MINERALOGICAL AND CHEMICAL DATA OF ALBERT FORMATION OIL SHALE

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Mineralogical and Chemical Data of Albert Formation Oil Shale

Mineral Resources Division
Department of Natural Resources
New Brunswick

Copies available by contacting:

Mineral Resources Division
Department of Natural Resources
P. O. Box 6000, Fredericton, N. B.
E3B 5H1

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Section 1

Mineralogical Data

1a. Mineralogical Data

L.H. King, 1963. Origin of the Albert Mines Oil Shale (New Brunswick) and its Associated Albertite. Department of Mines and Technical Surveys, Fuels and Mining Practice Division, Mines Branch Research Report R 115, Pages 5-11.

between the vein and the axis of the fold as mentioned previously, and is indicated in Wright's structural section of Figure 2.

Various early descriptions of the albertite vein have been summarized in a report by Ells (8) which describes the vein as varying in thickness from a few inches to 17 feet and extending laterally for 2,800 feet and to a depth of approximately 1,400 feet. All the workings are said to have been in oil shale. At the lower levels, as well as at the extremities, the vein passed into a brecciated mass of shale fragments closely cemented with albertite. Several smaller separate veins were also encountered in the underground workings.

Gussow (1) has described two main periods of deformation in the Moncton basin during Carboniferous time. The first occurred during Moncton time, following deposition of the Weldon, but preceded the Hillsborough. The second constituted the most intense orogeny and occurred at the close of the Mississippian, before late Hopewell time.

Emplacement of the albertite vein probably occurred during one of these orogenies, but the exact time is not clear from the structural evidence. The vein does not cut an overlying bed of conglomerate that is believed to be of Moncton age, but the exact nature of the oil shale-conglomerate contact is not evident. Wright concluded that the contact is either unconformable or faulted, while Norman (9) assumed it to be faulted. Gussow has mapped it as a nonfaulted contact. From considerations regarding the origin of the albertite that will be discussed later, an early emplacement is suggested.

PETROGRAPHIC DESCRIPTION

The rock descriptions in this section are representative of the five high-grade beds mapped by Wright (see Figure 2) and do not include in detail the lean and barren zones that constitute the remainder of the section. These high-grade beds are dominantly varved organic marlstones that vary from friable papery varieties to tough, blocky, distinctly laminated varieties. Also included in the high-grade zones are a few thin beds of massive dolomitic marlstone and some low-grade sandy marlstone with microbands of a clay-organic complex.

1. Blocky Laminated Marlstone

The blocky laminated variety represents the beds of richest oil shale which contains up to 30-40 percent organic matter and 30-40 percent of very fine inorganic grains identified as dolomite by X-ray techniques. The beds are generally highly contorted, and contain numerous microfolds and microfaults.

The laminae generally occur as couplets in which one is distinctly richer in organic matter than the other. Each couplet constitutes a non-glacial varve and the varves repeat in rhythmic fashion to give these rocks their conspicuous lamination.

The laminae range in composition from pure organic layers to almost organic-free crystalline dolomite; however, a typical couplet consists of a relatively pure organic lamina and one in which the dolomite grains are suspended, or barely touching, in a groundmass of structureless organic matter. Various types are shown at different magnifications in Photos 1 to 5.* Under plain light the boundaries are fairly distinct, but under crossed nicols they appear more gradational (Photos 3 and 4).

The thickness of the varves illustrated in Photos 1 and 2 is approximately 0.2-0.3 millimetre and is fairly representative; however, the extreme range in thickness for the specimens examined is from 0.05 to 2.0 millimetres. In the highly contorted beds, varve measurements in a given section can be quite apparent, due to variable orientations; therefore, the 2-millimetre extreme might be high.

The bulk of the organic matter has a low index of absorption and is generally translucent and structureless. Its colour is dependent on the thickness of the thin section. Since microspores are generally present, they have been used as an index in preparing the thin sections to a standard thickness. At a thickness where the spores are barely beginning to show as cherry red, most of the organic matter throughout the slide is lemon-yellow in colour. Boundaries between the pure organic laminae and the organic matter that occurs as a groundmass between mineral grains blend without any colour change, indicating that the properties of the two occurrences are very similar; however, the pure organic bands are anisotropic, indicating a higher degree of optical organization. The dominant structureless and uniform aspect of the organic matter, as well as the dispersed nature of the mineral grains through the organic groundmass, suggests that during deposition the organic matter was a gel-like mass. Subsequent metamorphism has polymerized the gel to a tough, resilient mass with properties similar to wurtzilite.

Although morphological structure in the organic matter is not prominent, it is nevertheless present. The most common structures occur as fusiform bodies of pure lemon-yellow organic matter, and range in length from approximately ten to several hundred microns. These bodies are exclusively defined by the surrounding mineral grains, as they show no ornamentation or colour differences at their boundaries. Structure is also completely absent within the bodies. Well-preserved examples are illustrated in Photos 6 to 9.

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* Photos 1-12 appear on pages 18-21.

The best preservations of fusiform bodies are often associated with either a partially or a fully developed inorganic cap or film on one side of the specimen (Photo 7). The optical properties of the cap compare most closely with anhydrite, so it is unlikely that the cap represents the remnant of a varve. More than likely the anhydrite was precipitated at the depositional interface and this possibly accounts for the excellent state of preservation of some of the fusiform bodies. As the state of preservation deteriorates, the bodies become more stringy and fibrous in outline and are not readily recognized. Vague outlines suggest that a fairly large proportion of the pure organic laminae originate from the fusiform bodies.

Other morphological entities, composed of brown organic matter, can be observed at high magnification in the organic groundmass between the mineral grains. Some of these forms appear to resemble the assemblage of bacteria, fungi and algae described by Bradley (10) from the Green River formation. Small yellow fusiform bodies can also be observed in the organic groundmass, but the bulk of the yellow groundmass is structureless and appears to completely wet the mineral grains.

The chief inorganic component is dolomite which is present in quantities up to 30-40 percent; thus, approximately 70-80 percent of these rocks is composed of organic matter and dolomite. The remaining 20-30 percent occurs as quartz and orthoclase feldspar, usually less than 20 microns in diameter. A portion of the quartz is secondary. These rocks also contain approximately 2 percent pyrite.

The dolomitic grains occur as extremely fine, more or less spherical crystals, some with a suggestion of reniform surfaces. These grains are mixed with even finer angular fragments. The grain size varies from 1 to 10 microns, and each grain constitutes a single crystal of dolomite. They are best illustrated in Photo 5. Occurrences of a similar aspect have been found in many Recent deposits and in the geological column (11), and are generally thought to have been precipitated through the activity of algae. Wood (12) has described such material as "algal dust". According to Bradley (13), euhedral carbonate crystals are more or less distinctive of the organic laminae in the richer oil-shale beds of the Green River formation.

If the grains are truly of organic origin, the highly reducing environment and the sedimentary pattern suggest that they were associated with planktonic organisms. Thus, the bulk of both the organic and inorganic constituents apparently rained down on the sedimentational interface. On the other hand, in some of the closely packed, dense laminae of dolomite the surfaces of adjacent grains sometimes conform suggesting a cellular pattern, but it is difficult to determine whether this is a primary feature.

The possibility of an inorganic origin for the dolomite crystals cannot be completely discounted, but it appears unlikely that they are oolitic, since neither concentric growth patterns nor nuclei are in evidence.

2. Papery Marlstone

These rocks have a lower organic content than the blocky varieties. The organic matter is lemon-yellow, but individual laminae of pure organic matter are less common. The carbonate content is also less, in the order of 20 to 30 percent, but is similar in size, structure, and composition. The feldspar and quartz content is higher and some mica is present. The grain size of the feldspar and quartz is larger, varying up to 60 microns in diameter. The increased detrital aspect imparts a certain vagueness to the varve development in this rock; however, the varves are still quite evident in thin section and average about 0.1 millimetre in diameter.

3. Low-grade Sandy Marlstone

The sandy marlstone consists of thin beds of detrital quartz and feldspar in a disorganized matrix of dolomitic ooze and organic matter, interbedded with thin layers of a clay-organic complex. The organic content of these rocks is less than 10 percent. The organic matter has a reddish tinge, indicating a change in composition from that of the organic-rich shales.

4. Massive Dolomitic Marlstone

The massive marlstone is also a mixture of detrital grains, ooze, and organic matter, but the beds are more thickly developed. A portion of the ooze consists of dolomitic spherical bodies, similar in some respects to the unicellular algae, Chlorellopsis coloniata Reis, described by Bradley (14) from the Green River formation. They are, however, much smaller (10 to 20 microns as compared with 103 to 122 microns) and are filled with reddish-brown organic matter instead of microcrystalline carbonate. They are illustrated in Photo 10.

5. Oil Shale Containing Albertite Veinlets

Specimens of oil shale containing albertite veinlets were obtained from the mine dump. Thin section studies of these specimens gave the first indication that the organic matter of the shale and the albertite differed considerably in composition. The differences are illustrated in Photos 11 and 12, where at a given thickness the organic matter of the shale is yellow while the veinlet of albertite is dark reddish-brown. Spores in the section are a deep red.

Similar results were also obtained by inserting a thin slice of albertite, a few millimetres in diameter, between two thicker slices of oil shale and mounting them in a lucite pellet before sectioning. Such a comparison of the relative light absorption of two organic components appears to be more critical than the method used by Hunt, Stewart and Dickey (15) whereby comparisons were drawn between infrared spectra of carbon disulphide extracts of the Green River beds and their associated "vein hydrocarbons". The latter technique compares only a fraction of the matter, and the spectra are not highly definitive unless they are examined on a quantitative basis.

PHYSICAL, CHEMICAL AND OPTICAL PROPERTIES

A sample of oil shale for detailed analysis of its organic matter was selected from Bed 1, Figure 2. The specimen was a conspicuously varved marlstone of the following composition: 37.5 percent organic matter, 32.3 percent dolomite, 0.3 percent sulphur, the remainder being quartz, feldspar, and minor constituents.

The organic matter was separated from the shale by a combination of methods, I and III, which are fully discussed in another report (16). In essence, the separation technique was a flotation in zinc bromide, followed by a hydrofluoric acid treatment. The albertite was obtained from a collection of the Fuels and Mining Practice Division and was purified by hand-picking.

The properties of the albertite and its organic separate were measured according to methods previously described (16), and the results are shown in Table 1.

The infrared spectra from which the quantitative data were obtained are shown in Figure 4. The similarities of the curves make it very evident that the infrared data are greatly enhanced by the quantitative treatment. In addition to the absorption regions considered in Table 1, both spectra show absorption in the 2.90-2.95 micron region, and the organic separate from the shale absorbs in the 10.35 micron region. It is not possible to treat the former region quantitatively, because of interference from moisture associated with the potassium bromide pellets. The 10.35 micron band is possibly olefinic and also shows in the albertite when run in Nujol.

The short wavelength region was checked by running the samples as a Nujol suspension and the spectra showed a broad OH absorption between 2.9 and 4.0 microns, indicating the presence of carboxyl groups. These polar functional groups are probably highly significant with regard to the origin of the albertite, and were probably stronger at the time of deposition.

TABLE 1

Physical, Chemical and Optical Properties of Albertite and the Organic Separate from the Albert Mines Oil Shale, plus Additional Data on the Green River and New Glasgow Oil Shales for Comparison with the Albert Mines Oil Shale

	No. 89 Albert Mines Oil Shale	No. 34, Albertite	Mahogany Shale, Green River 1/	No. 121 New Glasgow Oil Shale
Physical Properties:				
Colour in mass:	Brown	Black		Dark brown
Streak:	Light brown	Brown to black		Light brown
Tenacity:	Sectile and tough to grind	Brittle		Tough to grind
Fracture:	Conchoidal	Conchoidal		Conchoidal
Density, d^{25}_{4}:	1.006	1.078		0.984
Chemical Properties:				
Carbon, wt. %, ash-free	82.1	84.1	77.9	85.7
Hydrogen	10.7	9.4	9.7	11.4
Nitrogen	1.2	2.0	2.7	0.7
Sulphur	1.4	0.3	2.3	0.4
Oxygen	4.6	4.2	7.4	1.8
Ash	1.0	-	8.1	0.6
Volatile Matter:	93.0	69.3	93.0	92.8
Atomic H/C:	1.56	1.34	1.49	1.60
Atom % Carbon:	38.4	42.1	39.0	38.4
Aromaticity:	0.29	0.41	-	0.22
Solubility in CS_2:	3.1	1.8	-	-
Optical Properties:				
Refractive Index, n^{25}_{D}:	1.55	1.65	1.60	1.55
Infrared Data (in terms of relative absorptivity):				
Aliphatic groups:				
3.42 μ, CH_2	1.23	0.72		
7.27 μ, CH_3	0.05	0.09		
13.9 μ, CH_2 chain ...	0.067	0.031		
Aromatic CH, 11 - 14 μ total:	0.27	0.52		
Carbonyl, 5.87 μ:	0.13	0.23 2/		
Aromatic C=C, 6.27 μ	0.10	0.26		
Background at 5 μ	0.03	0.14		
Background at 8 - 10 μ	Considerably stronger in the albertite.			

1/ Properties after Forsman and Hunt (17).

2/ Albertite peak is broad, indicating additional groups.

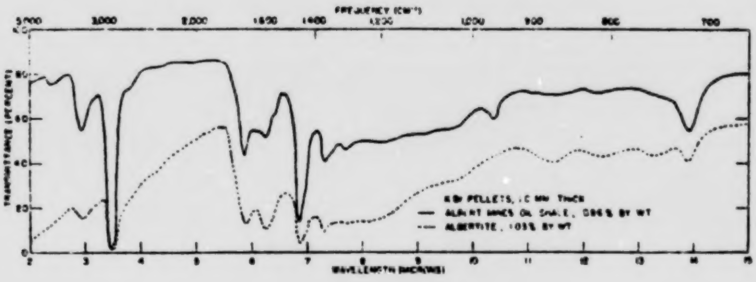


Figure 4 - Infrared spectra of albertite and the organic separate from the Albert Mines oil shale.

The data of Table 1 clearly show significant differences between the albertite and the organic separate from the shale. The fundamental reason for these differences between the majority of properties measured is the higher aromaticity of the albertite. This is indicated specifically by the values obtained for aromaticity using van Krevelen's densimetric analysis (18), as well as by the infrared data. Other properties sensitive to aromaticity confirm this evidence -- for example, the higher refractive index and atom percent carbon, as well as the lower volatile matter and atomic hydrogen-carbon ratio, shown by the albertite.

The degree of polymerization is high in both samples, as indicated by their low solubilities.

For a graphical presentation of the differences between the albertite and organic matter from the shale, as well as their relation to a much larger spectrum of natural organic matter from geological formations, the reader is referred to a previous report (16).

ORIGIN

Albert Mines Oil Shale

The presence of rhythmic bedding and the abundance of organic matter impart a unique aspect to the oil shale, and both characteristics imply a rather specific type of deposition. Formation and preservation of the fine laminae suggest deposition below wave and strong current action at an interface relatively undisturbed by benthonic organisms. Extreme conditions of quiescence, and lack of by-passing of the sediments, are also suggested by the extreme fineness of the grains. The deposit apparently rep-

1b. Mineralogical Data

G. Macauley and F.D. Ball, 1982. Oil Shales of the Albert Formation, New Brunswick. Department of Natural Resources Mineral Resources Division, New Brunswick, Open File Report 82-12, Pages 20-29, 162-165.

MINERALOGY

In North America, oil shales are still regarded primarily as a source of petroleum products; however, European experience indicates a much broader scope for ulitization of such deposits. At the Estonian operation in the Baltic Basin, not only are petroleum products and electricity generated as energy forms, the shale ash provides the raw material for road base, lime and sand bricks, lime fertilizer and cement (Õpik and Kaganovitch, 1981). At the Rohrback Zementwork, Dotterhausen, Germany, oil shale is burned in a fluidized bed to produce electricity and residue used to produce cement and mortar binder, a dual function for the oil shale (Schmitz, 1981). The potential multi-role function necessitates a full knowledge and understanding of the mineralogy of any oil shale deposit.

Two factors complicate determination of mineral components. Kerogen virtually surrounds most of the grains, inhibiting the acid reaction by which carbonate can be recognized: most samples remain almost inert in cold or hot 10% HCl solution. Detection of the harder quartz and feldspar detrital grains by scratching is also inhibited by the kerogen film. Much of the quartz-feldspar component is in the size range 20-60 microns (King, 1963), not discernible by normal visual inspection, including reflecting stereo-microscope examination. These problems are evident in the core and sample descriptions (Appendices 1 and 2) where mineral identification of both carbonates and terrigenous clastics have not been recorded. To obtain as much mineralogical data as possible, all samples acquired for geochemical investigation were also subjected to X-ray diffraction analysis.

Individual samples are denoted by core hole name, sample number and depth in metres. The sample numbers correspond to those along the right hand edge of the lithologic-geochemical log presentations (Fig. 4 and 5). The indicated zones refer to the lithologic units of the Albert Formation, including the Hiram Brook facies (HB), upper shale zone (US), Albert Mines zone (AM), the clay marlstone (CM) and dolomite marlstone (DM) units, and the Dawson Settlement (DS) and Round Hill (RH) facies.

Semi-quantitative results were obtained from diffraction peak heights and are reported in bar graph form (Figs. 6a, 6b and 6c) and as actual calculated percentages (Appendix 3). These computations represent relative rather than absolute values. Because of varying crystal shapes and sizes, quartz tends to be over-estimated whereas clays are recorded at less than true content, making no allowance for kerogen, which may be up to 40% of the rock material; consequently, most of the true contents for specific minerals will probably be somewhat less than indicated. This is not considered to be significant as the interpretations are herein based primarily on the relative changes in specific mineral content.

Several pronounced mineralogical relationships and compositional trends are strongly indicated from the limited number of samples analyzed: considerably greater sample control will be required to develop these concepts to their full potential of zonal and environmental recognition and correlation.

The carbonate minerals dolomite, calcite and siderite, terrigenous derived quartz, feldspar and clays, as well as clays and quartz from decomposition of feldspar, and the alteration zeolite analcime (from clays), comprise virtually the entire inorganic component. Each of these minerals is contained within distinct distributional patterns in the Albert Mines area: most of these patterns appear regionally applicable to other oil shale areas.

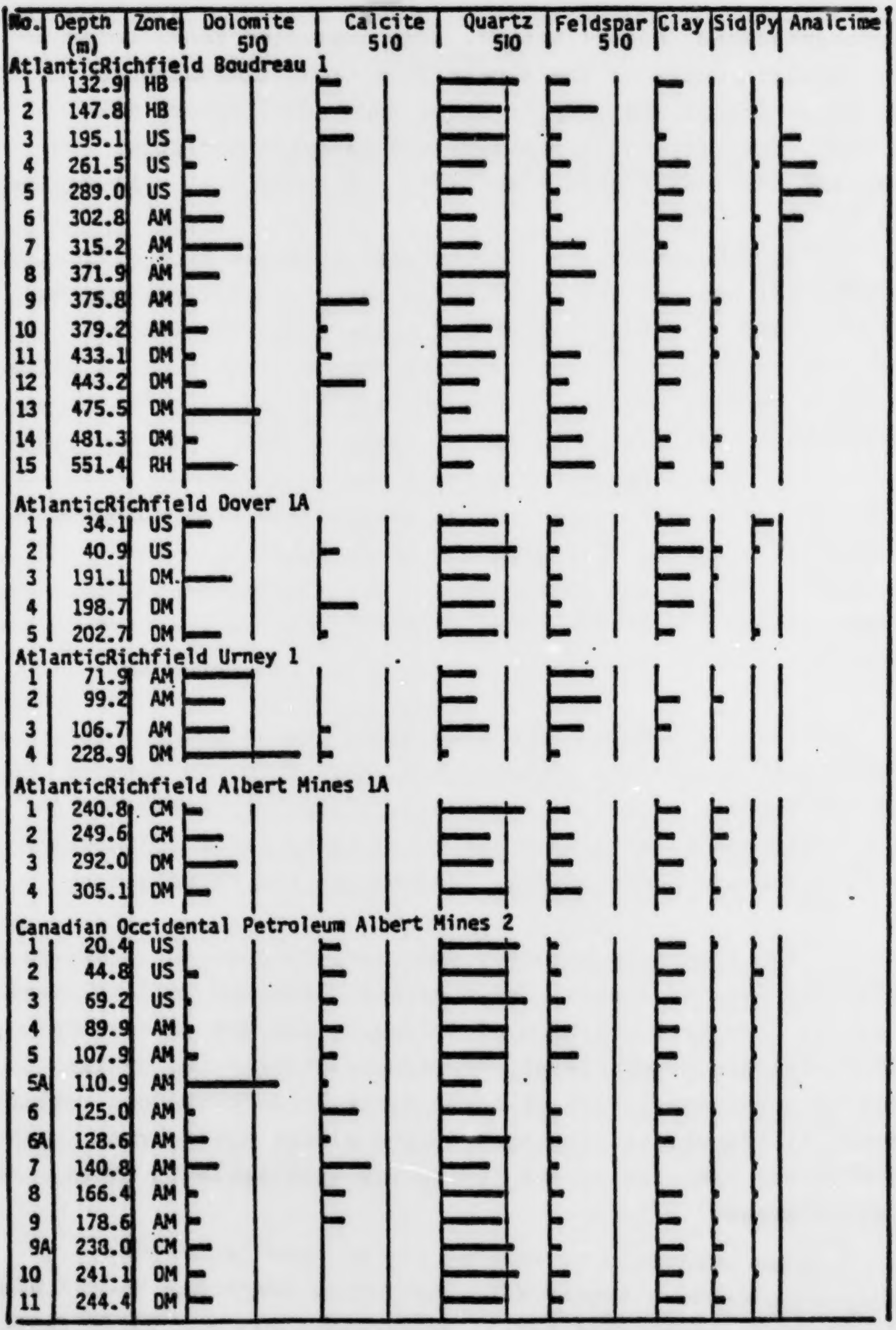


Figure 6a: Mineral distribution from X-ray diffraction analyses for Boudreau, Dover, Urney, Albert Mines

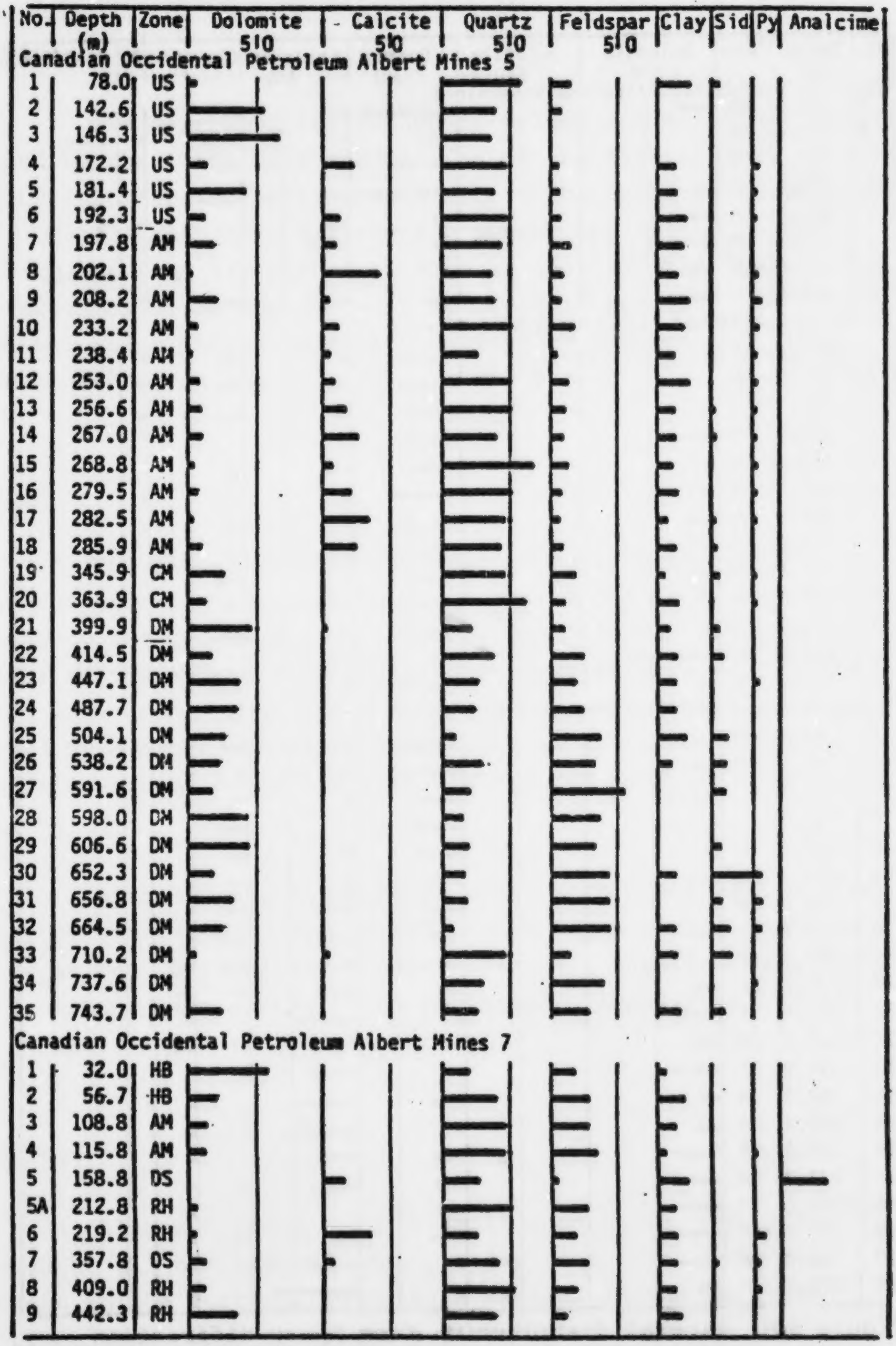


Figure 6b: Mineral distribution from X-ray diffraction analyses for Albert Mines

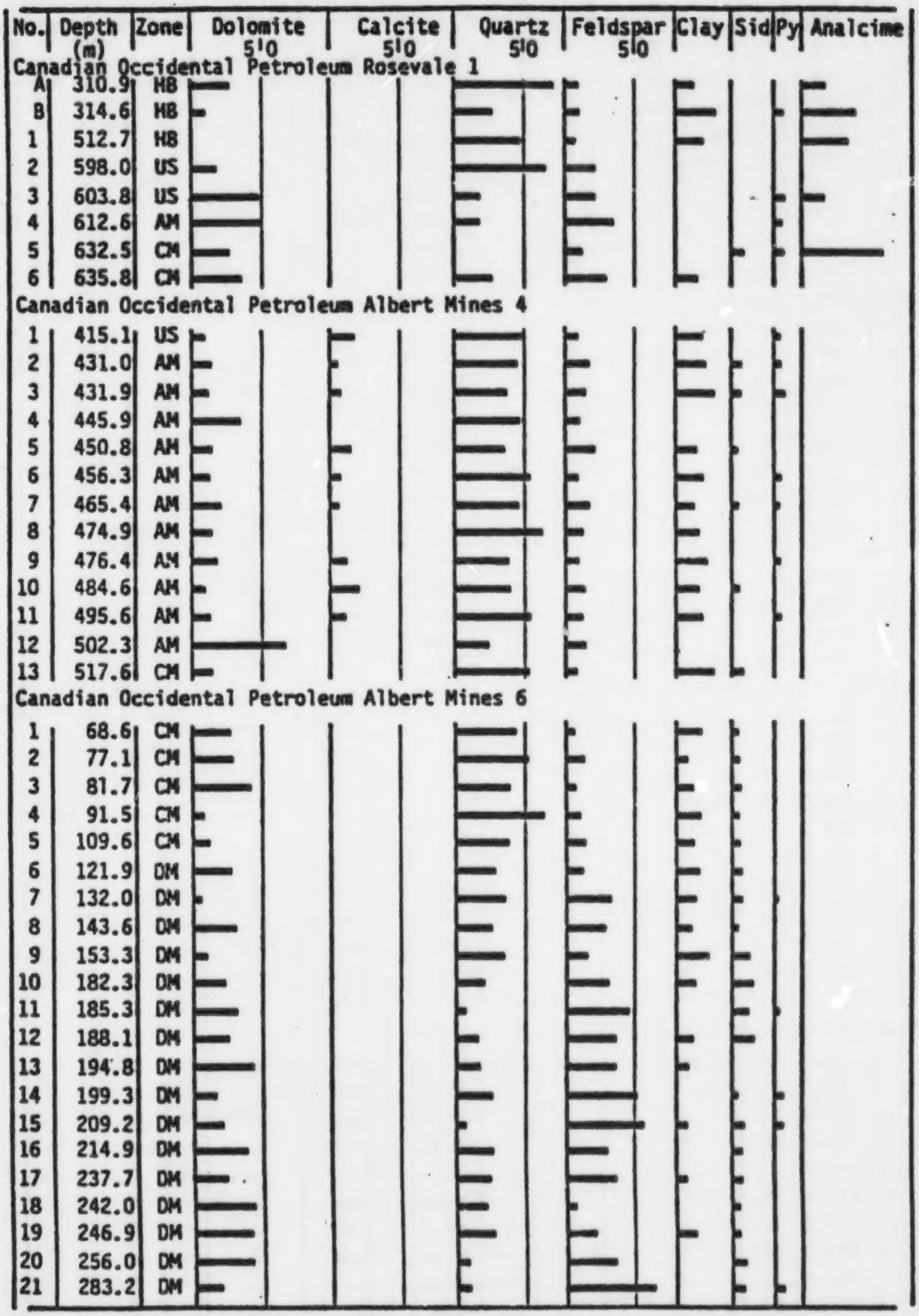


Figure 6c: Mineral distribution from X-ray diffraction analyses for Albert Mines, Rosevale

Dolomite

The general distribution of dolomite has already been defined by the lithologic subdivision of the Albert Mines area, whereby dolomite increases downward into the dolomite marlstone zone. Calculated X-ray diffraction percentage values in the Albert Mines zone are almost as high as those of the lower unit, but, after allowing for downward decrease in kerogen, the net dolomite, which increases at the expense of kerogen and clay, is much greater in the dolomite marlstone zone.

Calcite

The almost complete absence of calcite in samples below the Albert Mines zone in the Albert Mines area inversely relates to the dolomite distribution. Calcite-rich laminae are present in the Albert Mines and upper zones as well as calcite-filled fractures. This presence of calcite was possibly controlled by a minor change in conditions at the sediment-water interface whereby dolomitization was reduced upward in the section.

Although minor limestone zones were noted in the clay marlstone zone at Can. Oxy. Albert Mines 5 and within Round Hill facies at Can. Oxy. Albert Mines 7 (Fig. 4), significant calcite and limestone beds appear to be contained primarily within the Albert Mines zone and younger section.

Siderite

Although found only in small quantities, but present throughout all the sampled zones, siderite content increases downward in the section, reaching a maximum in the dolomite marlstone zone, thus correlating directly to dolomite in distributional pattern.

Quartz-Feldspar

Within the upper zone, the Albert Mines zone, and the clay marlstone zone, quartz predominates over feldspar in quantity, whereas the reverse relationship, feldspar dominant, is distinctive to the dolomite marlstone zone. Where feldspar is less than approximately 20% of the inorganic component, several forms appear to be present: above this value, albite predominates.

The reversing quartz-feldspar ratio is not indicative of changing source material, but results from the inhibition of diagenetic alterations of the feldspars under the carbonate-depositing environments of the dolomite marlstone zone (Berkeland, 1974). Decreased clay and quartz resulted as feldspar remained unweathered in contrast to their decomposition in the overlying zones.

Within the uppermost oil shale zones, quartz and feldspar occur in very fine silt size grains (20 to a maximum 60 microns) indicating that much of the quartz is a probable weathering product of the feldspar. In the dolomite marlstone zone, especially the lower beds of that section, coarser silt to sand size quartz grains are definite terrigenous detritus.

Clays

Also linked to the distributional trends of the dolomite and quartz-feldspar is a reduction of the clay content downward into the dolomite marlstone zone. The greater clay content above the dolomite marlstone zone is likely due to the combination of diagenetic alteration of the feldspar and an increased influx of detrital clay.

Mixed larger clays (montmorillonite) and illite are present throughout, generally with the mixed clays more common, and with a suspected relative increase in illite in the dolomite marlstone zone. Kaolin appears to be only sporadically present from the limited data of this study.

The reduced clay content of the dolomite marlstone zone was anticipated from plots of the water recovery data of the Fischer assays (Figs. 4 and 5). An increased water yield of the clay marlstone zone, the "shaliest" oil shale zone was the basis of initial zonal definition as the water was postulated to be derived from the clay minerals. This appears to have been a correct assumption from the X-ray diffraction results and from the results of the recent Fischer assays, where water yields virtually duplicate those conducted by AtlanticRichfield and Can. Oxy. in 1968 and 1976. This duplication infers the water to be mineral content, not related to pore and fracture filling or near surface ground waters.

Analcime

The zeolite, analcime, was located in several cores within the upper zone, Albert Mines zone and clay marlstone zone. It is missing from the dolomite marlstone zone and is generally present in zones of low feldspar content.

Although primarily a groundmass mineral of alkali-rich basic igneous rocks, analcime is also an alteration product of alkaline waters, rich in sodium, in volcanic ash and clay minerals. This zeolite was formed by such reaction in the Green River oil shales of the central western United States (Berry and Mason, 1959) and may also here result from alteration of the clay minerals of the Albert oil shales. The absence of analcime from the dolostone and dolomite marlstone beds correlates directly to the reduced clay content of those lithotypes.

Others

The sporadic presence of pyrite is not surprising as the association between organic matter and pyrite is well documented. Iron and sulphur are present in most depositional environments and under reducing conditions, as would be expected in a lacustrine setting, ferrous iron, hydrogen sulphide and sulphur would react to produce iron sulphides.

Beta-quartz, a high temperature form, occurs irregularly in almost all zones and all core samples. Because no distributional pattern is evident, no significance can be projected for the occurrence of this mineral. Amphibole and apatite are accessory heavy minerals and gypsum is probably of diagenetic origin.

In summary, the quantitative distribution of quartz, clay, calcite and analcime defines a mutually related mineral group, which contrasts inversely to a second mutual group, dolomite, siderite and albite feldspar. These groups are not exclusive of each other but are each dominant to specific lithologic types. The quartz-clay-calcite-analcime group typifies the upper zone shales, the laminated marlstones of the Albert Mines zone and the clay marlstone, whereas dolomite-siderite-feldspar identifies the dolomite marlstone and dolostones. These groupings are not reflective of variable source material, but are controlled primarily by the geochemistry of the depositing environments. Although both are indicative of the upper zones, calcite and analcime do not co-exist in any significant amounts.

Whether or not these mineralogical variations will be significant on a regional basis over the Moncton subbasin is conjectural from the scope of this study; however, two positive notes may here be interjected. During the general examination of the surface sections to the west in the Sussex and Apohaqui areas, the cementing material of Hiram Brook sandstones was noted to be calcareous in upper intervals and siliceous in the lower section, similar to the calcite distribution of the Albert Mines oil shales.

On the north-northwesterly flank of the Moncton subbasin, much of the section of the Albert Formation along the Kingston Uplift (Fig. 2) has variably been described as shale, dolostone and marlstone. Two spot samples, not oil shales, were collected. An upper sample, dark grey laminated shale, contains high quartz, lower feldspar and analcime, whereas a lower sample, dark grey massive hard marlstone, has increased dolomite, lower quartz and significant albite (Appendix 3). These spot samples indicate that the indicated mineralogic zonation may be significant over much of the basinal area.

STRUCTURES

The oil shale cores display numerous primary sedimentary and imposed diastrophic features. Some difficulty was encountered in recognizing bedding plane structures. The limited area available to examine bedding within cores placed some restrictions upon the observers, as did the physical degeneration of frequently large intervals of core because of inadequate storage.

Primary Sedimentary Structures

Stratification is the primary sedimentary structure of the oil shale intervals. Bedding thickness varies widely, from over a metre in thickly bedded strata of the massive dolostones and dolomite marlstones (Plate 1.c) to less than a millimetre in thinly varved strata of the laminated marlstones (Plate 2.b). Graded bedding and irregular stratification are commonly associated with the regular stratification. The vast majority of the bedding and laminations noted are planar: examples of irregular stratification are generally the result of penecontemporaneous deformation. The quiescent anoxic environment of deposition for the marlstones and dolostones would not produce the sediment movement required to create dynamic sedimentary structures.

Bedding plane lamination is the only depositional structure of the laminated and clay marlstones. Even the interbedded dolomite marlstones and local dolostone bed within the Albert Mines zone exhibit only lamination, being barren of penecontemporaneous deformation features. Within the optimum oil shale zones, the light-dark carbonate-kerogen varves are a striking feature of the deposits.

AtlanticRichfield Urney 1

1: 71.9 m (236'); 7.5 l/t; marlstone, brown massive to brown laminated dolomite, very silty with quartz to 40% and some siltstone laminae to thin beds; in part almost varved with dark laminae which appear grey to brown and may be clay or kerogen; uniform bedding dip at 25° to core axis

2: 94.2 m (309'); 7.9 l/t; marlstone, brown to grey, hard, very silty with quartz to 40% and silt laminae and lenses; minor brown kerogen laminae impart distinct bedding appearance, also evident from silt variations; hard, may be closer to siltstone rather than marlstone; 30° uniform dip to core axis

3: 106.7 m (350'); 12.1 l/t; marlstone, brown to greyish-brown; finely laminated to almost varved; in part silty in grains and laminae, less than 10% quartz silt; contorted bedding with microfolds and faults, averaging 50° dip to core, some slickensided zones

4: 228.9 m (751'); 33.8 l/t; marlstone, medium brownish-grey to brown; finely laminated to almost varved, numerous dark grey quartz, silt laminae; dip about 70° to 80° to core axis

APPENDIX 3

X-RAY DIFFRACTION RESULTS

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
AtlanticRichfield Albert Mines 1A													
1	240.8	CM	10	-	57	12	9	6	-	6	-	-	-
2	249.6	CM	26	-	34	16	4	7	-	6	1	-	βQtz:6
3	292.0	DM	33	-	37	17	tr	8	-	3	2	-	βQtz:tr/Apa
4	305.1	DM	16	-	47	21	4	6	-	5	1	-	-
Canadian Occidental Petroleum Albert Mines 2													
1	20.4	US	tr	13	57	6	tr	15	4	3	2	-	Apa
2	44.8	US	9	17	44	8	9	10	-	-	3	-	-
3	69.2	US	2	10	61	10	5	8	2	-	2	-	-
4	89.9	AM	4	15	50	14	6	8	tr	2	1	-	Apa
5	107.9	AM	9	10	47	20	4	7	-	2	1	-	Apa
5A	110.9	AM	66	5	29	tr	-	tr	-	-	-	-	-
6	125.0	AM	5	26	38	9	6	12	tr	2	2	-	-
6A	128.6	AM	15	6	52	8	10	9	-	tr	-	-	-
7	140.8	AM	21	36	34	6	tr	tr	-	tr	3	-	-
8	166.4	AM	8	13	45	9	5	9	3	4	2	-	βQtz:2/Apa
9	178.6	AM	9	14	42	9	tr	15	-	2	3	-	βQtz:6
9A	238.0	CM	16	-	52	7	5	13	-	7	-	-	-
10	241.1	DM	11	-	55	13	6	9	-	3	3	-	βQtz:4/Apa
11	244.4	DM	18	-	45	8	10	8	-	7	-	-	-
Canadian Occidental Petroleum Albert Mines 4													
1	415.1	US	9	15	49	7	6	8	tr	3	3	-	-
2	431.0	AM	12	5	41	14	8	12	-	5	3	-	-
3	431.9	AM	11	8	36	12	11	13	-	3	6	-	-
4	445.9	AM	44	tr	47	9	-	tr	-	tr	tr	-	-
5	450.8	AM	13	13	33	19	1	10	tr	2	tr	-	-
6	456.3	AM	11	7	53	7	8	11	-	-	3	-	-
7	465.4	AM	20	7	45	14	4	7	-	2	1	-	-
8	474.9	AM	15	-	61	10	5	8	-	tr	-	-	-
9	476.4	AM	17	10	36	7	9	11	-	tr	3	-	βQtz:7
10	484.6	AM	9	20	39	12	7	7	-	3	tr	-	Apa:tr
11	495.6	AM	12	9	51	10	7	8	-	-	3	-	-
12	502.3	AM	66	-	23	11	-	tr	-	tr	tr	-	-
13	517.6	CM	12	-	50	7	12	11	-	8	-	-	-
Canadian Occidental Petroleum Albert Mines 5													
1	78.0	US	6	-	57	13	9	12	tr	3	-	-	-
2	142.6	US	54	-	38	8	tr	tr	-	-	-	-	-
3	146.3	US	65	-	35	-	-	tr	-	-	-	-	-
4	172.2	US	12	22	46	5	11	tr	-	tr	4	-	-
5	181.4	US	42	-	38	5	3	10	tr	-	2	-	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
6	192.3	US	11	11	49	7	7	13	tr	tr	2	-	-
7	197.8	AM	19	9	41	13	8	10	-	-	tr	-	Amph:tr
8	202.1	AM	2	41	35	9	4	7	-	-	2	-	-
9	208.2	AM	20	4	34	8	11	10	-	-	6	-	Amph:tr
10	233.2	AM	5	10	49	15	10	8	-	-	3	-	-
11	238.4	AM	3	55	24	4	6	6	-	tr	2	-	-
12	253.0	AM	8	8	49	11	8	14	-	tr	2	-	-
13	256.6	AM	9	17	49	10	5	7	-	1	2	-	-
14	267.0	AM	10	26	39	9	6	6	-	2	2	-	-
15	268.8	AM	4	8	65	11	4	5	-	tr	3	-	-
16	279.5	AM	6	20	50	8	6	8	-	2	-	-	-
17	282.5	AM	4	33	46	7	tr	7	-	2	1	-	-
18	285.9	AM	10	24	41	7	5	7	-	2	-	-	βQtz:4
19	345.9	CM	25	-	47	17	tr	5	-	2	2	-	Apa:2
20	363.9	CM	12	-	60	10	6	8	-	tr	2	-	Apa:2
21	399.9	DM	46	4	20	10	4	4	-	3	-	-	βQtz:9
22	414.5	DM	16	-	36	22	5	7	-	7	-	-	βQtz:7
23	447.1	DM	39	tr	24	18	tr	11	-	-	4	-	βQtz:4/Apa:tr
24	487.7	DM	35	-	21	22	5	7	-	-	-	-	βQtz:5
25	504.1	DM	29	-	6	37	7	11	-	10	-	-	-
26	535.2	DM	22	-	28	32	4	5	-	9	-	-	-
27	591.6	DM	17	-	18	53	tr	tr	-	8	-	-	βQtz:4
28	598.0	DM	43	-	13	44	-	tr	-	-	-	-	-
29	606.6	DM	45	-	19	31	tr	tr	-	5	-	-	-
30	652.3	DM	19	-	16	42	4	7	-	-	4	-	βQtz:3
31	656.8	DM	32	-	17	41	-	tr	-	5	5	-	-
32	664.5	DM	25	-	7	43	6	5	-	10	4	-	Gyp:tr
33	710.2	DM	6	3	45	13	11	tr	-	13	-	-	βQtz:9
34	737.6	DM	29	-	29	38	tr	tr	-	-	1	-	Apa:3
35	743.7	DM	24	-	23	28	8	8	-	9	-	-	-

Canadian Occidental Petroleum Albert Mines 6

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
1	68.6	CM	25	-	43	6	9	8	-	5	-	-	βQtz:4
2	77.1	CM	27	-	50	10	3	5	tr	3	tr	-	Gyp:2
3	81.7	CM	41	-	37	6	-	10	-	6	-	-	Apa
4	91.5	CM	7	-	63	10	7	10	-	3	tr	-	Apa
5	103.6	CM	11	-	39	13	9	13	-	5	3	-	βQtz:7/Apa
6	121.9	DM	28	-	26	11	8	7	-	8	tr	-	βQtz:12
7	132.0	DM	4	-	35	31	5	8	-	8	2	-	βQtz:7
8	143.6	DM	30	-	26	25	tr	9	-	3	2	-	βQtz:5
9	153.3	DM	9	-	33	15	11	10	-	12	tr	-	βQtz:10
10	182.3	DM	22	-	19	29	6	6	-	14	-	-	βQtz:4
11	185.3	DM	30	-	6	45	tr	tr	-	10	3	-	βQtz:6
12	188.1	DM	26	-	14	35	4	6	-	15	-	-	-
13	194.8	DM	41	-	16	31	tr	9	-	3	-	-	-
14	199.3	DM	15	-	23	50	tr	tr	-	2	5	-	βQtz:5
15	204.2	DM	21	-	6	54	4	4	-	7	4	-	-
16	214.9	DM	39	-	25	29	tr	tr	-	7	-	-	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
17	237.7	DM	22	-	24	37	tr	8	-	6	-	-	βQtz:3
18	242.0	DM	41	-	21	5	-	tr	-	3	tr	-	Apa
19	246.9	DM	40	-	25	20	5	7	-	3	-	-	Apa
20	256.0	DM	41	-	8	35	-	tr	-	8	-	-	Apa:8
21	283.2	DM	17	-	9	61	tr	tr	-	7	6	-	-
Canadian Occidental Petroleum Albert Mines 7													
1	32.0	HB	58	-	19	17	tr	6	tr	tr	-	-	-
2	56.7	HB	11	-	40	29	7	8	5	-	-	-	-
3	108.8	AM	15	-	45	27	8	tr	5	-	tr	-	-
4	115.8	AM	13	-	47	33	3	2	-	-	2	-	-
5	158.8	DS	-	16	25	6	6	8	7	-	-	32	-
5A	212.8	RH	8	-	49	27	4	4	4	-	-	-	-
6	234.4	RH	4	36	25	17	tr	9	4	-	5	-	-
7	357.8	DS	12	7	40	26	4	4	3	2	2	-	Apa
8	409.0	RH	11	-	50	19	3	5	4	tr	5	-	-
9	442.3	RH	34	-	38	10	6	10	tr	-	-	-	βQtz:2
AtlanticRichfield Boudreau 1													
1	132.9	HB	-	13	57	13	10	tr	7	-	-	-	-
2	147.8	HB	-	23	43	32	tr	tr	tr	-	2	-	-
3	195.1	US	7	23	44	9	5	tr	tr	-	-	12	-
4	261.5	US	7	-	31	14	6	9	7	-	3	23	-
5	289.0	US	25	tr	21	6	6	9	4	-	-	29	-
6	302.8	AM	28	-	28	9	10	7	tr	tr	3	15	-
7	315.2	AM	41	-	27	25	tr	5	-	-	2	-	-
8	371.9	AM	23	-	45	32	tr	tr	-	-	-	-	-
9	375.8	AM	6	35	23	10	7	16	-	3	tr	-	-
10	379.2	AM	15	5	35	25	5	8	3	2	2	-	-
11	433.1	DM	7	9	39	22	6	12	-	3	2	-	-
12	443.2	DM	14	32	27	13	7	7	tr	-	tr	-	-
13	475.5	DM	54	tr	20	26	tr	tr	-	tr	tr	-	-
14	481.3	DM	8	tr	47	23	9	tr	-	5	2	-	βQtz:6
15	551.4	RH	32	tr	21	31	tr	10	-	6	-	-	-
AtlanticRichfield Dover 1A													
1	34.1	US	18	-	40	9	7	9	5	-	12	-	Amph:6
2	40.9	US	-	11	54	6	6	11	3	6	3	-	-
3	191.1	DM	32	tr	36	8	10	7	5	2	-	-	Amph:6
4	198.7	DM	tr	27	39	9	10	9	6	-	-	-	-
5	202.7	DM	26	5	40	14	4	6	tr	-	5	-	-
Canadian Occidential Petroleum Rosevale 1													
A	310.9	HB	24	-	70	8	6	4	-	-	-	13	-
B	314.6	HB	9	tr	17	8	12	7	8	-	4	35	-
1	512.7	HB	-	tr	46	6	10	8	tr	-	-	30	-
2	598.0	US	17	-	63	20	tr	tr	-	-	-	-	-
3	603.8	US	48	-	17	20	-	tr	-	-	3	12	-

No.	Depth (m)	Zone	Dol %	Cal %	Qtz %	Fspar %	Il %	MLC %	Ch/K %	Sid %	Py %	Anal %	Other %
4	612.6	AM	50	-	15	32	-	tr	-	-	3	-	βQtz:tr
5	632.5	CM	26	-	tr	10	-	tr	-	4	4	56	-
6	635.8	CM	33	-	26	28	6	7	-	-	-	-	-
AtlanticRichfield Urney 1													
1	71.9	AM	49	-	21	30	tr	-	-	-	-	-	-
2	94.2	AM	27	-	23	34	4	8	-	4	-	-	-
3	106.7	AM	30	6	32	23	tr	9	tr	-	-	-	-
4	228.9	DM	84	9	4	3	-	tr	tr	tr	-	-	-

Canadian Occidental Petroleum Albert Mines 2 (surface weathering product)

127.1 Rozenite - 68%; Gypsum - 9%; Quartz - 7%; βQuartz - 12%; Pyrite - 4%

Abbreviations:

Dol - Dolomite
Cal - Calcite
Qtz - Quartz
Fspar - Feldspar
Il - Illite
MLC - Mixed Layer Clays
Ch/K - Chlorite and/or Koolinite
Sid - Siderite
Py - Pyrite
Anal - Analcime
Amph - Amphibole
Apa - Apatite
Gyp - Gypsum
tr - trace

1c. Mineralogical Data

J.K. Worth, 1977. Oil Shale and Lithofacies, Albert Formation, Hillsborough Sub-Basin, New Brunswick. In Report for Canadian Occidental Petroleum Ltd., Calgary, Alberta, Pages 40-59.

SECTION IV

DEPOSITIONAL ENVIRONMENTS OF THE ALBERT FORMATION, HILLSBOROUGH SUB-BASI

IV.A GENERAL:

Within the lithostratigraphic succession of the Albert formation analysed in this report, seven depositional environments were noted. A combined deltaic - lacustrine depositional model analagous to that applied in the Tertiary successions of Wyoming, Utah and Colorado has been used to designate these environments.

Three lacustrine sub-environments are noted in the Hillsborough Sub-basin. The oil yield from the finer-grained rocks deposited in these environments increases from the margins toward the centre of the depositional basin as follows:

(i) the lake margin carbonate flat environment, generally yielding less than 10 US gpt oil,

(ii) the marginal open lacustrine environment, generally yielding between 10 and 20 US gpt oil,

& (iii) the central open lacustrine environment, generally yielding from 20 to in excess of 50 US gpt.

Four non-bituminous depositional sub-environments are also recognized in this sub-basin:

(iv) the interdeltaic environment,
(v) the fluvial deltaic environment,
(vi) the alluvial deltaic environment,
& (vii) the evaporite environment.

Descriptions of these depositional sub-environments follow.

IV.B DESCRIPTIONS OF DEPOSITIONAL ENVIRONMENTS IN THE ALBERT FORMATION:

B.1 : The Lacustrine Margin Carbonate Flat Sub-Environment:

The strata of the lake margin carbonate flat sub-environment are peripheral to those of open lacustrine environments. Basinward intercalation with lacustrine sediments and lateral intercalation with interdeltaic sediments is common in the Hillsborough Sub-basin.

The major lithologies of the lake margin carbonate flat sub-enviro ment are claystone and shale with minor sandstone, siltstone, dolomite, sandy and silty claystone and shale, and "rip-up" breccia. Rock colour are commonly greyish and range from light to dark grey, grey-brown, gre tan, grey-green, green, and less commonly darker shades of brown.

Rock types are normally massive to thinly bedded; less commonly thinly laminated rock types are present. Sandstone and siltstone stringers and carbonate lenses are also present. No fossils are noted. Mud cracks described during the 1975 survey and by Greiner (1962) are also characteristic of this sub-environment.

X-ray diffraction studies were performed on 16 fine-grained rocks from the carbonate flat sub-environment by ARCO in 1966. Dolomite and quartz are by far the most abundant minerals in this Sub-basin. Il and albite are also present, but in lesser amounts. The x-ray diffract data from these 16 samples is summarized below. Five examples of mineralogical composition in this environment from ARCO drillholes are given in Figures 5 and 6.

Mineral	Samples containing Mineral
Dolomite	16/16
Quartz	16/16
Illite	16/16
Albite	15/16

continued:

Mineral	Samples containing Mineral
Kaolinite	11/16
Analcime	11/16
Potash Feldspar	8/16
Calcite	7/16
Chlorite	5/16
Montmorillonite	5/16
Pyrite	5/16
Siderite	3/16

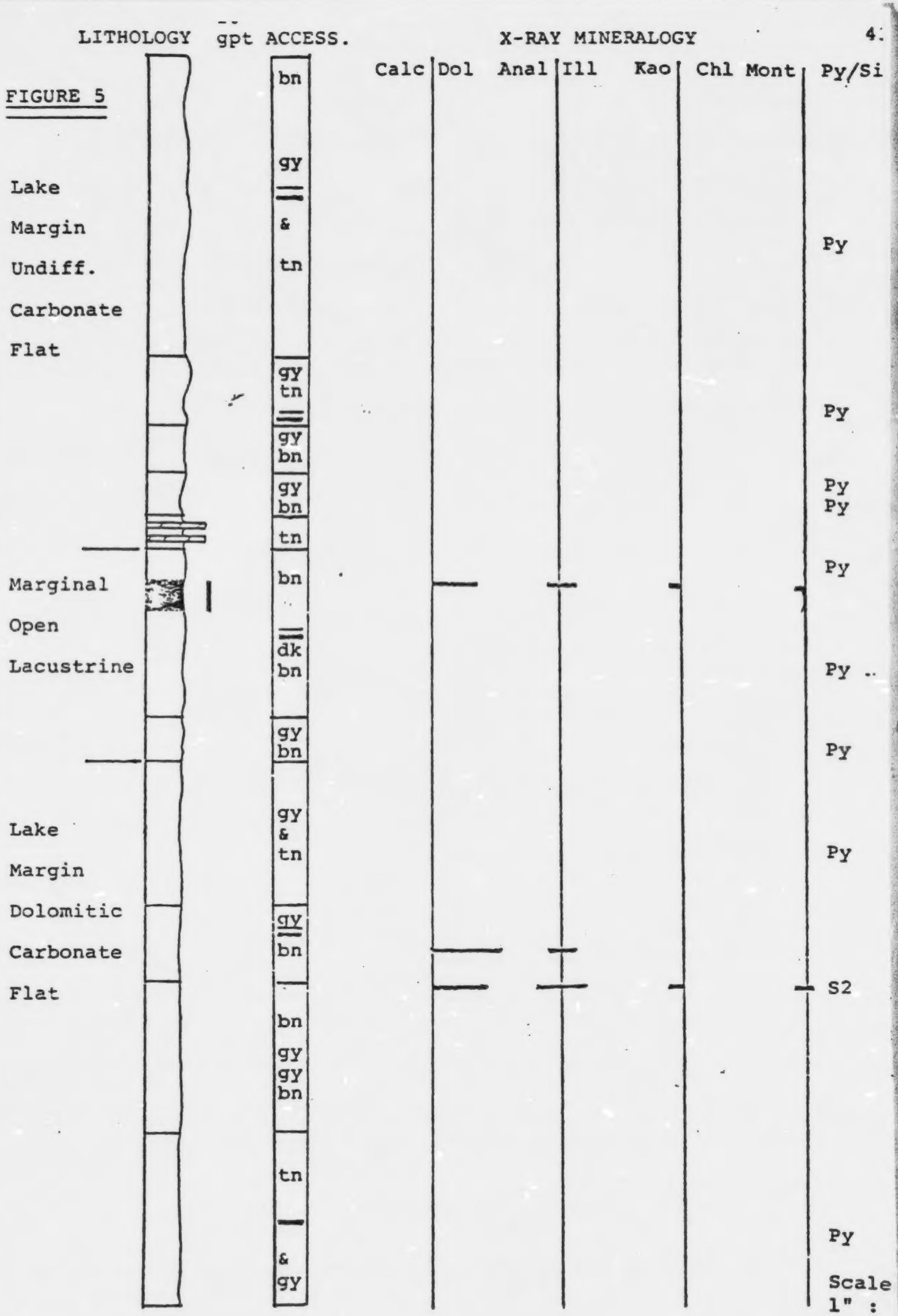
Dolomite is the main carbonate mineral on the lake margin carbonate flat sub-environment, although basinward, calcite does occur in sub-equal amounts associated with dolomite. Rarely, both calcite and dolomite are absent; siderite, then becomes the major carbonate constituent of the rock.

Strata deposited on the carbonate flats have undergone extensive dolomitization. The dolomitization process is no doubt similar to that proposed for the dolomitization of carbonates in the Green River formation of Wyoming. In this process, carbonate flats were repeatedly exposed and concentrated brines with high Mg/Ca ratios developed near the surface of the flats precipitating either primary dolomite or recrystallizing pre-existing calcite.

Analcime is characteristic of the lake margin carbonate flats although it is by no means restricted to this depositional setting. Wher it is found in adjacent sub-environments, it is always found in very small amounts. Analcime appears to have formed during the dolomitization process on the flats. It is commonly associated with minor amounts of albite and appears to be an alteration product of albite formed in an alkaline environment.

In addition, albite and other aluminosilicates appear to have been

FIGURE 5


LITHOLOGY
gpt
ACCESS.
X-RAY MINERALOGY
Calc
Dol
Anal
Ill
Kao
Chl
Mont
Py/Si
Lake Margin Undiff. Carbonate Flat
Marginal Open Lacustrine
Lake Margin Dolomitic Carbonate Flat
bn
gy
&
tn
gy
tn
gy
bn
gy
bn
tn
bn
dk
bn
gy
bn
gy
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bn
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Py
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Py
S2
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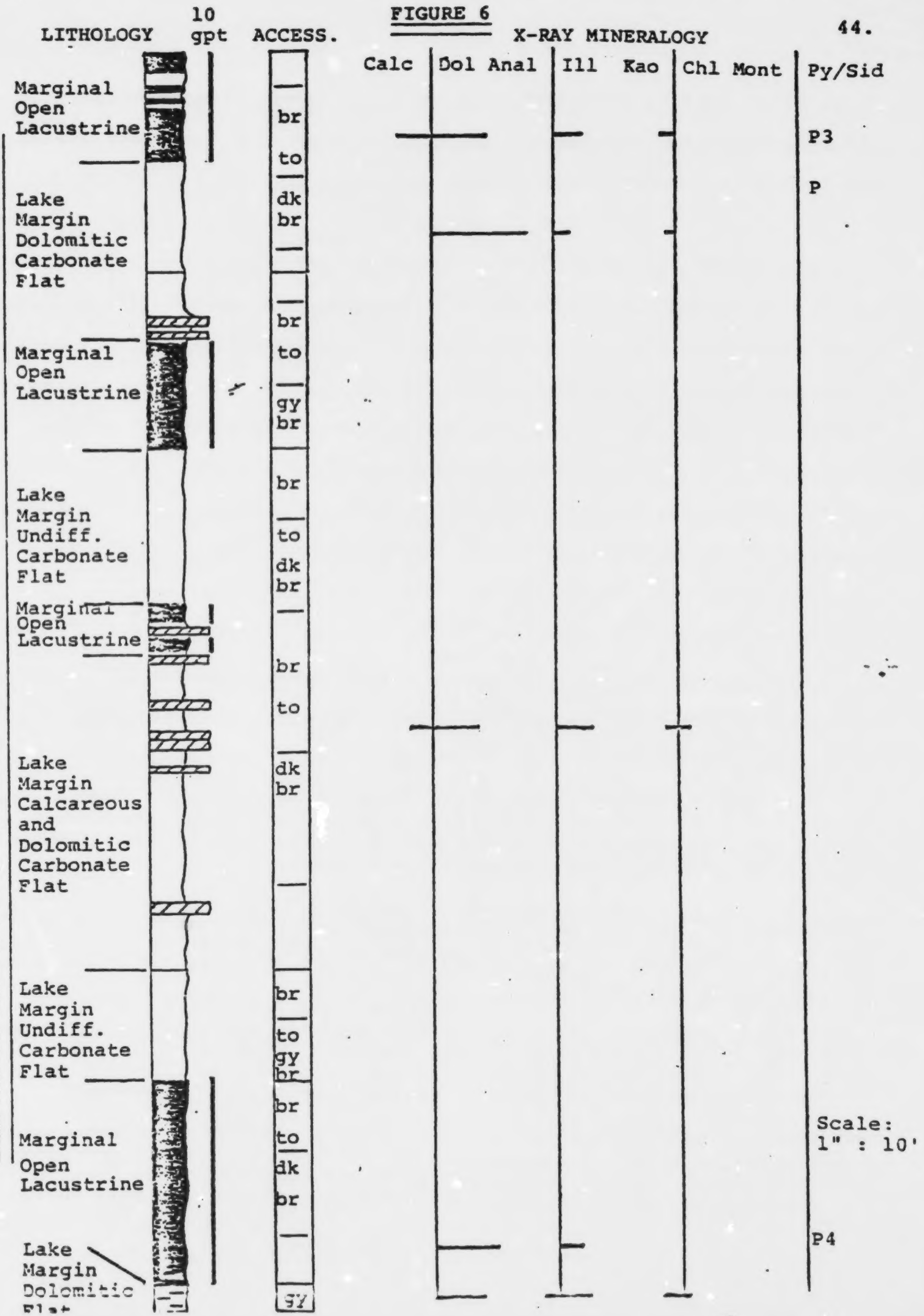
Scale
1" :

MARGINAL LACUSTRINE AND LAKE MARGIN CARBONATE FLAT, ARCO BOUDREAU DRILLHOLE

FIGURE 6


LITHOLOGY
10
gpt
ACCESS.
X-RAY MINERALOGY
Calc
Dol Anal
Ill
Kao
Chl Mont
Py/Sid
Marginal Open Lacustrine
Lake Margin Dolomitic Carbonate Flat
Marginal Open Lacustrine
Lake Margin Undiff. Carbonate Flat
Marginal Open Lacustrine
Lake Margin Calcareous and Dolomitic Carbonate Flat
Lake Margin Undiff. Carbonate Flat
Marginal Open Lacustrine
Lake Margin Dolomitic Flat
br
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P3
P
P4
Scale:
1" : 10'

LAKE MARGIN CARBONATE FLAT AND OPEN LACUSTRINE ENVIRONMENTS, ARCO ROSEVALE DRILLHOLE altered to produce illite through the process of silicate hydrolysis in this alkaline environment. This process normally converts albite to kaolinite to montmorillonite to illite.

In the oil shale bearing sections of Utah, the lake margin carbonate flat environment is characterized by carbonate beds which grade basinward from ostracode and oolite grain-supported rock types to mixed mud and grain-supported carbonates. Here, calcite is the most common carbonate. The lake margin carbonate flat environment in Utah is fossiliferous and contains gastropods, pelecypods, ostracodes, oncolites, and stromatolites The grain-supported carbonates appear to represent shoals on the flats; the fossiliferous mud-type carbonates were deposited closer to the centre of the basin.

The main differences beyween the lake margin carbonate flat environments in Utah and similar environments in the Hillsborough Sub-bas are summarized below:

(i) The carbonate flats in the Albert formation were characterized by extensive dolomitization. This reflects not only the degree of subaerial exposure, but also the alkalinity of the environment, both of which were greater in the Hillsborough Sub-basin.

(ii) The lake margin carbonate flats of the Hillsborough Sub-basin are devoid of fossils; in Utah, basinward parts of this sub-environment are highly fossiliferous. This is possibly the result of dolomitization, however, the lack of stromatolites suggests that exposure of the flats was the main cause for lack of organic remains.

(iii) The carbonate flats of the Hillsborough Sub-basin are characterized by a relatively high clastic content. This is not the case in Utah. The clastic content of the Albert formation in this sub-environmer is attributed to the influence of nearby interdeltaic sediments.

and (iv) The Hillsbrough Sub-basin appears to have been characterized by rapid transgressions of the basin over the carbonate flats producing rip-up breccias. Regressions were probably equally rapid; nowhere are the oncolite or oolite deposits noted which characterize this sub-environment in Utah.

B.2 : The Marginal Open Lacustrine Sub-Environment:

This sub-environment is transitional between the lake margin carbonate flat environment and the central open lacustrine sub-environment. Extensive interfingering of strata from these three sub-environments is noted in the Hillsborough Sub-basin. Rarely, the marginal open lacustrine environment interfingers with coarser clastic strata of the interdeltaic sub-environment.

The main lithologies of the marginal lacustrine sub-environment are claystone and shale with oil shale, minor dolomite, limestone, siltstone, and sandstone. Rock colours are generally grey-brown and range to light and dark brown; grey and dark grey colours are also commo The darker brown lithologies are commonly associated with higher oil yields and represent the basinward extension of this sub-environment.

Rock types from the marginal open lacustrine sub-environment are normally thinly laminated to thinly bedded and less commonly massive wit rare sandy and silty laminae and stringers. Carbonate lenses are also common.

X-ray diffraction studies were carried out on 20 fine-grained rocks from the marginal open lacustrine environment of the Hillsborough Sub-bas in the 1966 ARCO oil shale programme. Quartz is the most abundant minera with calcite and/or dolomite. albite and illite as common accessories. The results of this x-ray study are summarized below.

Mineral	Samples containing Mineral
Quartz	20/20
Albite	20/20
Illite	20/20
Dolomite	14/20
Potash Feldspar	13/20

continued ...

Mineral	Samples containing Mineral
Calcite	12/20
Kaolinite	7/20
Pyrite	4/20
Siderite	4/20
Analcime	3/20
Montmorillonite	3/20
Chlorite	2/20

Dolomite and calcite appear to occur in sub-equal amounts in the carbonate rocks of this sub-environment. Rarely, where both are absent, siderite is the carbonate component. The presence of dolomite in this sub-environment attests to the processes of dolomitizati here as well as on the carbonate flats. In the marginal lacustrine setting, however, the degree of dolomitization does not appear to have been as extensive as on the adjacent flats.

The amount of illite in rocks of the marginal open lacustrine sub-environment is generally much greater than the amount of illite found along the carbonate flats. This also attests to the hydrolysis of aluminosilicates under highly alkaline conditions. The amount of albite present is also normally higher than that found on the carbonate flats. This suggests that the levels of alkalinity in this sub-environment fluctuated considerably. Under moderately reducing conditions, quartz and illite are commonly produced; under very highly reducing conditions, however, illite is not produced and albite or potash feldspar forms instead.

Analcime is present in the marginal open lacustrine environment, but only in a few samples. In this environment it is also considered to have formed from the alteration of aluminosilicates such as albite under highly alkaline conditions.

Several examples of the mineralogy of rocks from the marginal open lacustrine sub-environment are given in Figures 5 and 6.

B.3: The Central Open Lacustrine Sub-Environment:

In the central open lacustrine sub-environment, shale, oil shale, and bituminous dolostones are the most common rock types. This depositional setting interfingers with the marginal open lacustrine sub-environment and rarely with the interdeltaic sub-environment. Rock colours generally range from brown to dark brown and brownish-black. Less commonly, colours are dark grey and grey. The lithologies are generally thinly to finely laminated to thinly banded; wavy to highly-contorted laminae and bands are also common. As is the case with the marginal lacustrine sub-environment, no benthonic fossils have been noted from this sub-environment. The only organic remains are rare fish fossils and fish scales.

Only four samples were x-rayed from the central open lacustrine sub-environment in the ARCO oil shale programme. Quartz, albite and illite are the most common minerals. This data is summarized below:

Mineral	Samples containing Mineral
Quartz	4/4
Illite	4/4
Albite	4/4
Siderite	4/4
Calcite	2/4
Potash Feldspar	2/4
Kaolinite	2/4
Dolomite	1/4
Analcime	1/4
Montmorillonite	1/4
Pyrite	1/4
Chlorite	0/4

The mineralogy of the central open lacustrine environment is perhaps best illustrated in Figure 7, a plot of the mineralogy of the high-yielding oil shale zone at Albert Mines. In this Figure, the central open lacustrine sub-environment predominates the intersection from 230' to 650'. Here, the major minerals are quartz and illite with calcite as the main carbonate mineral. Oil yields range between 10 and 40 US gpt. A dramatic change in mineralogy accompanies the transition downward into the "slumped oil shale zone" from about 800' to the bottom of the hole. The slumped zone is probably marginal open lacustrine in origin. It is characterized by high dolomite, no calcite, relatively little quartz, a large increase in albite and and large decrease in illite. Oil yields from the slumped zone are commonly between 10 and 15 US gpt.

These mineralogic changes bear comparison with those found in the Piceance Creek Basin of Colorado at the"Blue Marker", the boundary between the Garden Gulch Member and the overlying Parachute Creek Member. Although the organic content of oil shales on either side of this marker bed varies little, the strata of the Garden Gulch Member are characterized by high quartz and illite with minor feldspar and dolomite. Above the "Blue Marker", in the Parachute Creek Member, the quartz and illite contents decrease dramatically whereas the dolomite and feldspar contents increase sharply. In the depositional setting of the Piceance Creek Basin, this change was apparently produced as the water increased beyond the silica/alumina solubility limit at about pH 10. The reverse of this is found in the Albert succession in the Hillsborough Sub-basin; a highly alkaline depositional environment became somewhat less alkaline. This environmental change, however, was associated with a sharp increase in the kerogen content of the oil shales. The same transition is noted in Figure 8 in ARCO Boudreau 1 at 1480' and in Figure 9 in ARCO Dover 1A at 810'.

B.4: The Interdeltaic Sub-Environment:

The interdeltaic sub-environment is lateral to the coarser-grained fluvial deltaic sub-environment. Generally strata of this sub-environmen intercalate with those of the lake margin carbonate flat or the marginal open lacustrine sub-environments. The interdeltaic sub-environment is especially common in the northern part of the study area. Here, it is peripheral to major influxes of sand across the Stony Creek and Dover Oilfields.

The interdeltaic sub-environment is characterized by fine- to medium-grained sandstone, siltstone, and shale. Rock colours range from light to medium grey and grey brown.

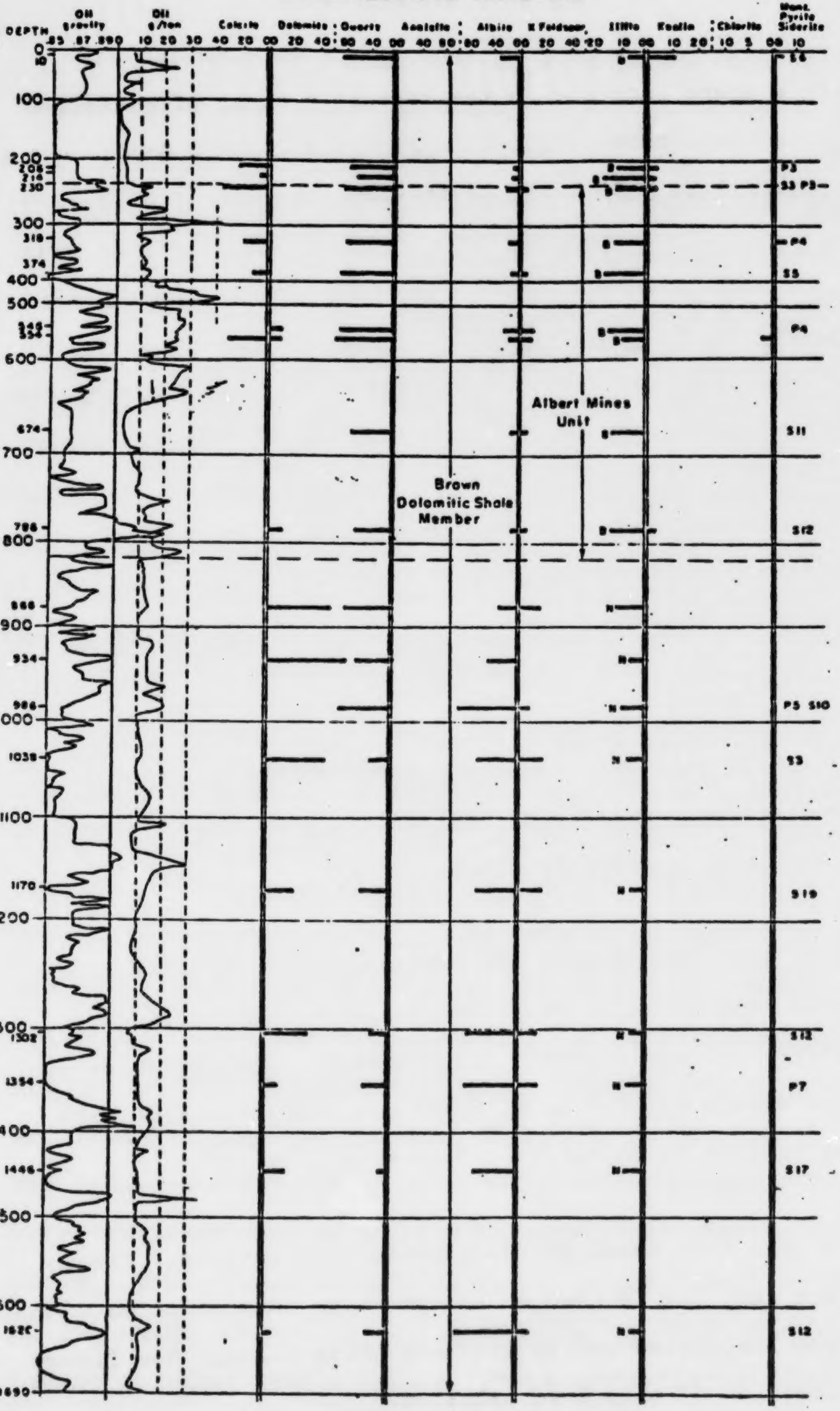
Sandstone of the interdeltaic sub-environment is normally fine to medium grained, but locally, contains pebbles and discontinuous stringers of shale, dolomitic shale, and dolomite. The sandstone is commonly massive with a scoured basal contact. Siltstone and shale in this setting tend to be thinly banded to thinly bedded.

No fossils have been noted in the interdeltaic setting. Finer-grained rocks are very low in kerogen except where intercalation with the marginal open lacustrine sub-environment takes place. See Figure 12 for an illustration of this intercalation.

URE 7

ARCO-Albert Mines #1"A"

MINERALOGICAL ANALYSIS



B = Broad Peak
N = Narrow Peak
P = Pyrite

S = Siderite
Mont = Montmorillonite (Plotted)
7 = Peak Height

FIGURE 3

ARCO Boudreau #1

MINERALOGICAL ANALYSIS

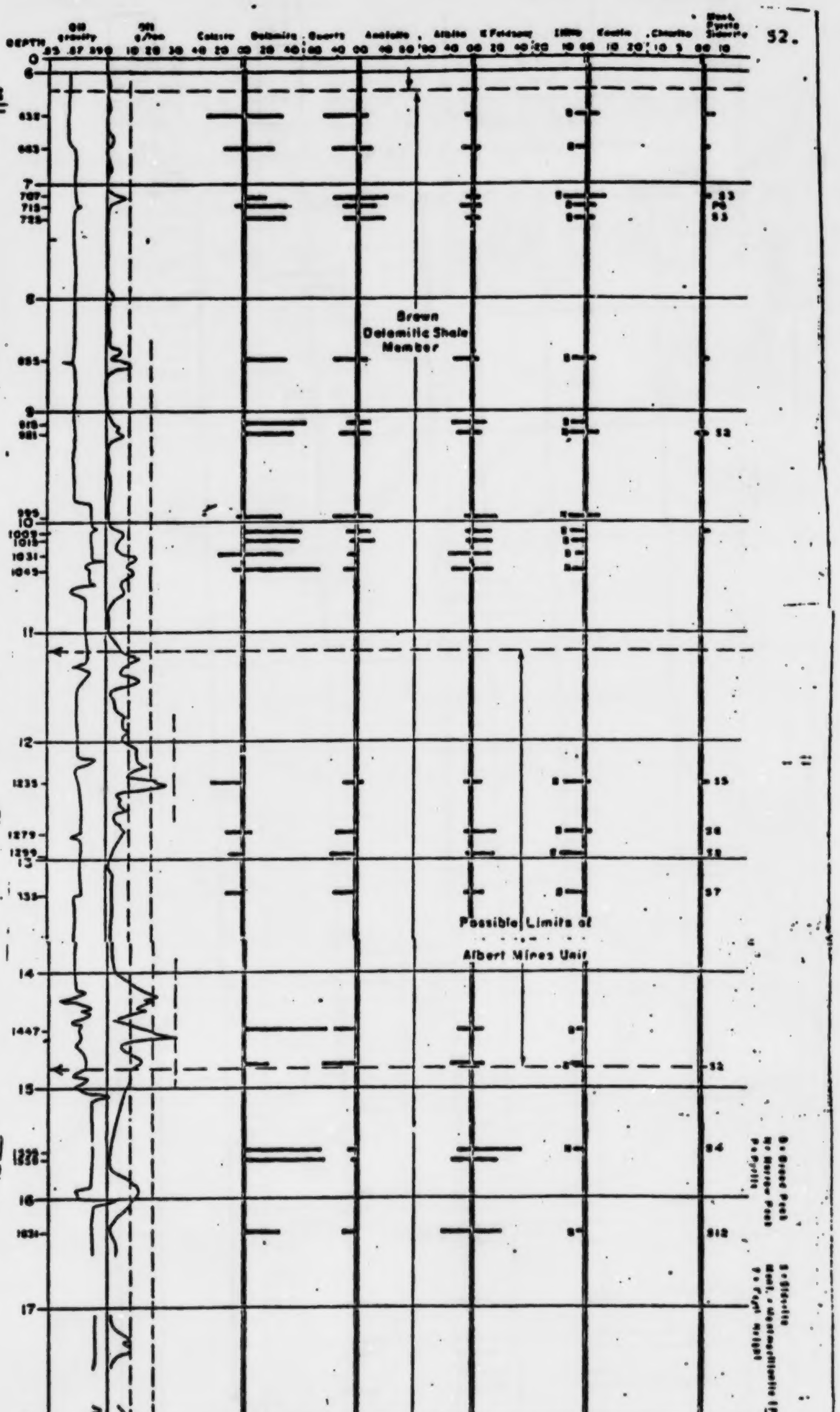
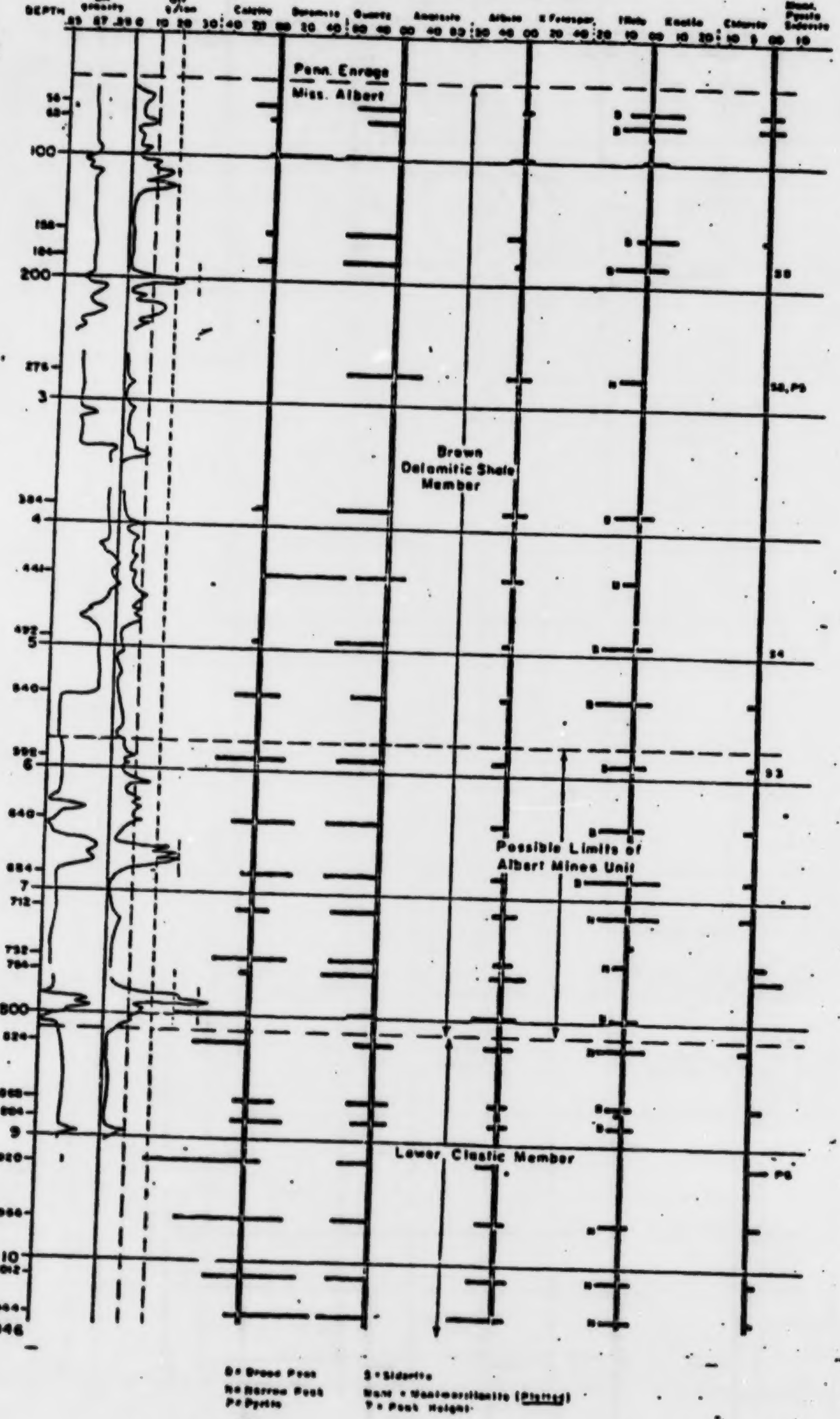
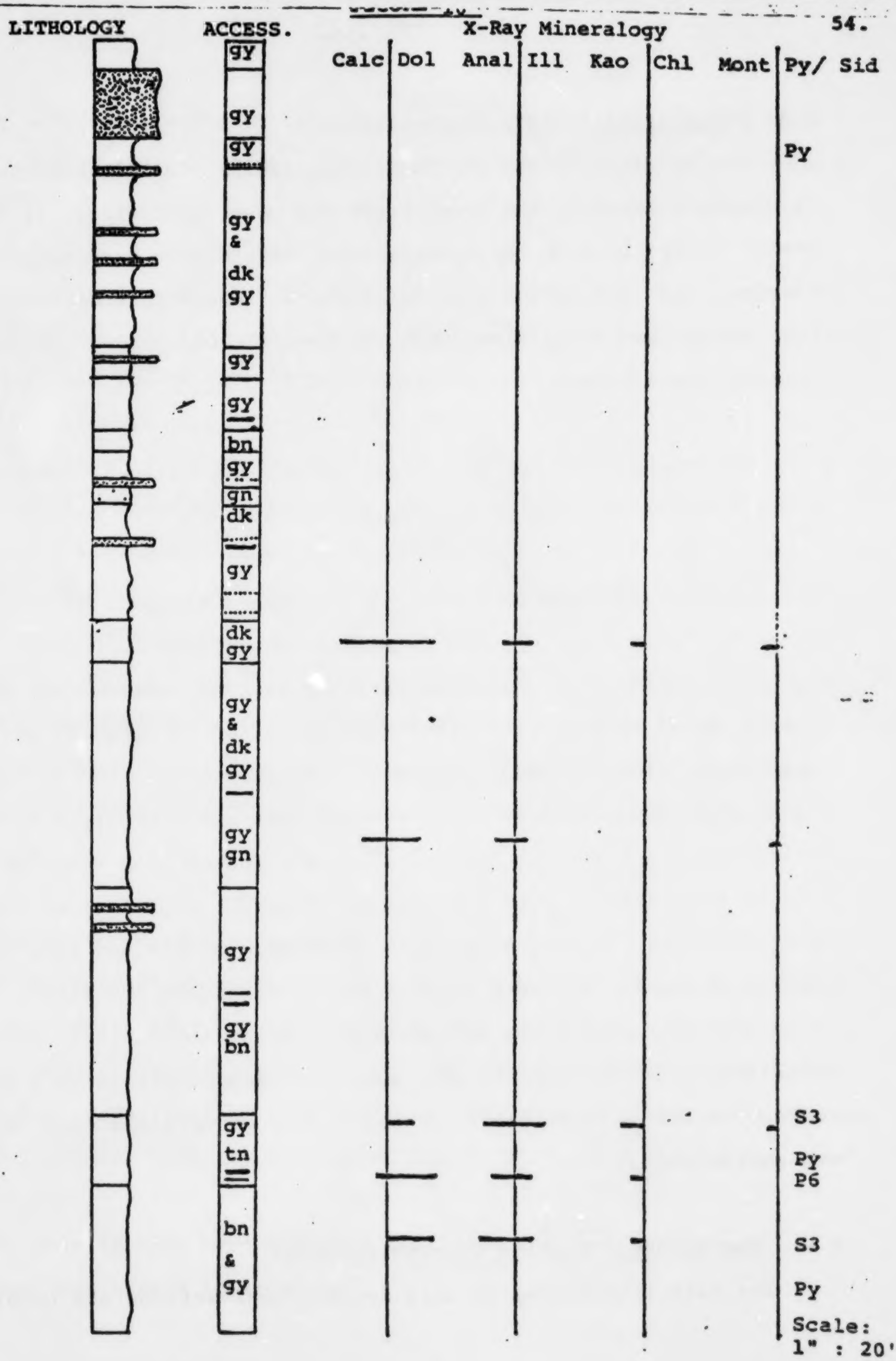


FIGURE 9

ARCO Dover #1 "A"

MINERALOGICAL ANALYSIS




LITHOLOGY
ACCESS.
X-Ray Mineralogy
Calc
Dol
Anal
Ill
Kao
Chl
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S3
tn
Py
P6
bn
S3
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gy
Py
Scale:
1" : 20'

LAKE MARGIN CARBONATE FLAT AND INTERDELTAIC ENVIRONMENTS, ARCO BOUDREAU DRILLHOLE

B.5: The Fluvial-Deltaic Sub-Environment:

In the Hillsborough Sub-basin, the fluvial-deltaic sub-environment is commonly found in the Stony Creek and Dover Oilfields. It commonly grades laterally into the interdeltaic, lake margin carbonate flat, and marginal open lacustrine sub-environments. Where intercalation with the lake margin carbonate flat sub-environments takes place, dolomitic interbeds are common.

The coarser-grained rock types of this depositional setting are med grey to medium grey-brown and light grey-brown.

Cyclic deposition reflecting advances and retreats of this deltaic sub-environment onto adjacent depositional settings is common. Generall the cycle begins with a scoured basal contact of conglomerate into finer-grained strata. The first unit deposited is normally medium-grain relatively "clean" conglomerate with dolomitic cement and dolomitic shale stringers. Pebbles in this basal unit are commonly sub-rounded to well-rounded and smaller pebbles often are coated with rinds of dolomite This is succeeded by poorly-sorted conglomerate comprised of larger sub-rounded to sub-angular pebbles with clay matrix and rare dolomitic shale stringers. The next unit is pebbly sandstone containing abundant shale and dolomitic shale stringers with dolomitic cement. Soft sediment injection is common. Gradually, pebbly sandstone yields to a mixture of rocks from the interdeltaic, carbonate flat or marginal open lacustrine sub-environments.

-fan

B.6: The Alluvial Deltaic Sub-Environment:

The main lithologies in this depositional setting are conglomerate, pebbly sandstone, and sandstone associated with minor siltstone, mudstone, shale, and marlstone. The finer-grainer lithologies are commonly pebbly.

The main distinctions between the alluvial deltaic sub-environment and the fluvial deltaic setting are the lack of good sorting and rounding of clasts and the mixture of red to purple with greyish rock colours in the alluvial setting.

The major rock types found in the alluvial deltaic setting are massive; the minor lithologies generally occur as stringers or are thinly bedded or banded. No fossils have been noted in this setting and no bituminous rocks are present.

The alluvial deltaic sub-environment is not common in the Hillsbrough Sub-basin. It is normally intersected toward the base of the formation or where the formation grades into the overlying Weldon(?) formation.

B.7: The Evaporite Sub-Environment:

This sub-environment is noted only to the south of the Stony Creek and Dover Fields near the top of the Albert succession. It is characterized by massive rock salt, anhydrite, and some glauberite. Intercalated with these evaporites are grey and less commonly red siltstone, mudstone, and shale bands, commonly brecciated due to the upward flow of the salt.

No fossils have been noted in the evaporite sub-environment. No bituminous strata intercalate.

C. IMPLICATIONS ON OIL SHALE DISTRIBUTION:

Three depositional settings are recognized as containing oil shale in the Hillsborough Sub-basin:

(i) the lake margin carbonate flat sub-environment, yielding less than 10 US gpt;

(ii) the marginal open lacustrine sub-environment, yielding between 10 and 20 US gpt;

& (iii) the central open lacustrine sub-environment, generally yieldin from 20 to in excess of 50 US gpt.

Oil yields increase basinward, hence identification of the carbona flat depositional setting should provide data pertaining to the locatio of higher yielding basinward depositional settings when combined with isopach, sand/shale, and clastic ratios.

Oil shale occurrences in the Albert Mines area are low in the stra igraphic section and can be divided into those within the basal "slumpe zone which yield from 10 to 20 US gpt and those within the zone overlyi the slumped zone which yield from 10 to 50 US gpt (See Figure 7).

In the Stony Creek and Dover areas, a similar basal occurrence of oil shales is recognized, although the "slumped" zone has not been note These lower occurrences are overlain by several thin oil shale occurren near the top of the Albert succession (See Figure 9).

One of the most intriguing changes in the depositional setting in the Hillsborough Sub-basin is the decrease in the alkalinity of the environment in the Albert Mines, Dover and Boudreau areas near the base of Zone 5. This change is marked by a transition in mineralogy from a lower dolomite-albite suite to a quartz-illite suite which marks the base of Zone 5. The change is also reflected in higher oil yields from the upper mineralogic suite.

The lowering of alkalinity in the Hillsborough Sub-basin is coincident with the influx of sand-shale in the Stony Creek - Dover area (See Plates V and VI). The influx of relatively fresh water accompanying this deltaic advance appears to have lowered the pH of the depositional basin as evidenced by mineralogical changes and undoubtedly raised the water level of the depositional environment.

During the deposition of the high-yielding oil shales of Zones 5 and 4, the central open lacustrine and marginal open lacustrine sub-environments appear to have predominated in the Albert Mines area (See Plates V and VI). At the same time, lake margin carbonate flat and interdeltaic environments interrupted by rare lacustrine transgression predominated elsewhere in the Sub-basin.

The depositional interval depicted by Zone 3 (Plate VII) was characterized by a partial retreat of the sand-shale facies from the northern parts of the study area. In the Albert Mines area, the depositional setting was mainly lake margin carbonate flats with rare transgressions of the marginal lacustrine environment. This attests to a lowering of the water level in the depositional basin. Lacustrine deposition (?) on a modest scale persisted only in the Stony Creek and Dover areas near the site of clastic influx.

These conditions persisted during the deposition of Zones 2 and 1 which are characterized by the complete and partial withdrawal of the sand-shale lithofacies (See Plates VIII and IX).

Based on a study of the depositional environments of the Albert formation in the Hillsborough Sub-basin, therefore, it is concluded that:

(1) The onset of sedimentation characterized by a high kerogen content coincided with the advance of the deltaic complex into the study area. This influx of relatively fresh water lowered the alkalini of the water in the depositional basin possibly to a point where planktonic fauna proliferated. At the same time, the water level in the depositional basin was raised and the margins of the kerogen-bearin lacustrine depositional environments expanded.

(2) Succeeding events which appear related to a change in the role of the Westmorland Arch in this Sub-basin, resulted in the withdrawal of the deltaic complex and shrinking of the lacustrine margins. Kerogenous sedimentation became restricted to localities adjacent to th sites of fresh water influx. This process of withdrawal of the lacustrine environment culminated in the deposition of evaporites.

and (3) Therefore, the sites of maximum oil shale deposition will be relatively low in the Albert succession. Evidence to date suggests that the main site centred around the Albert Mines area which early in the depositional history of the Albert formation was characterized by lacustrine sedimentation.

1d. Mineralogical Data

J.Y. Wright, 1982. Petro-Canada, St. Joseph Oil Shale Project, Westmorland County, New Brunswick, Pages 23-59.

MINERALOGICAL ANALYSIS

1. Introduction

The purpose of the mineralogical analyses (by X-ray diffraction) run on oil shales from various locations within the St. Joseph project area was to continue the work started by Macauley (1982).

It was hoped that his subdivisions of the Frederick Brook facies for the Albert Mines area could be extended across the Petitcodiac River and throughout the St. Joseph project area.

The samples selected were as follows:

Core Samples

	# Samples
Petro Canada Dover #2	87
Petro Canada Boudreau #1	17
Petro Canada Dover #1	41
Atlantic Richfield Dover #1A	7
Atlantic Richfield Boudreau #1	7

Surface Samples

Locality	
Downing Creek	20
Boyd Creek	9
Bill's Creek	3
Le Blanc Creek	3

The surface samples are located by number on the appropriate geological map (in pocket).

2. Sampling Procedures

Grab Samples

A 5 cm sample was grabbed every 9 m from top to bottom of the Petro-Canada Dover No. 1 core. A few similar samples were taken from the Arco Dover No. 1A and Arco Boudreau No. 1 cores to complement the samples previously taken by Macauley and Ball. These, along with a suite of hand specimens collected during the mapping program, were submitted to Petro-Canada's research laboratory for X-ray diffraction analysis.

Continuous Core Intervals

The core arrived from the drill in boxes 1.5 m long and, once logging had been completed, the selected samples were marked off in the most convenient manner, by the row, hence the samples are generally approximately 1.5 m in length. The selected intervals were cut in half on a specially modified rock saw (see photo at the back of this report) and one half shipped to Calgary where the core was halved again at Petro-Canada's research laboratory. This provided enough material for the various analyses and allowed a quarter core to be retained for ready reference.

Core Laboratories in Calgary handled the crushing of the samples, sending part to their Aurora, Colorado laboratory for Fischer Assay and returning the remainder to Petro-Canada for Rock-eval and X-ray diffraction analysis.

3. Laboratory Techniques

Samples and Sample Preparations

Core samples: 100 g from each crushed sample from Core Laboratories was separated out by quartering for XRD analysis.

Surface samples: The submitted sample, or a representative part of it was taken for XRD analysis. This was first broken up in a jaw crusher into small pieces.

Bulk samples: The picked core or surface sample was pulverized in a shatter-box for approximately 30 seconds. A slide (supplied by Philips) was made with part of this bulk sample by dry packing for XRD analysis.

Grain size separation: The remainder of the bulk sample was poured into a 250 mL beaker. About 100 mL of distilled water was added and stirred until the powder was completely wet. The wetted powder was agitated in a sonicator for about 10 minutes to disaggregate the particles. The sonicated suspension was allowed to sit for about 10 minutes after which the suspension was poured into a 1L measuring cylinder. This process was repeated at least three times and finally the whole sample was poured into a measuring cylinder. Distilled water was added until the water column was about 40 cm long. A stopper was placed over the cylinder which was shaken vigorously until the powder formed a uniform suspension. The suspension was allowed to settle and the timer started.

Separation of 2.0-0.2μ and <0.2μ fractions: The suspension was allowed to settle for a total of 23h:10 minutes, after which the top 30 cm of suspension was siphoned off and transferred to a 1L centrifuge bottle. This suspension containing the <2μ particles, was centrifuged to separate the solid from the water. The water was drained off carefully such that the solids in the bottom were not much disturbed and drained off. Residue was stirred (separately) into a uniform suspension and about 0.5 mL of the suspension was pipetted and uniformly spread throughout a 22 m circular cover glass embedded into a hole of the same size and thickness machined into the standard sample holder. The water was allowed to evaporate so that the solid formed a uniform thin layer over the cover glass. These slides were used for XRD analysis as untreated samples.

Glycolation: After the untreated clay fraction slides were analyzed by XRD, they were left in a desiccator containing ethylene glycol for 24 hours. These glycolated samples were then analyzed by XRD.

Heating: The slides containing the 2um fraction were put into a furnace pre-set at 550°C for three or more hours and were then analyzed by XRD.

XRD qualitative and quantitative analyses: All XRD analyses were performed on a Philips PW 1730 XRD unit equipped with pulse height analyzer, graphite monochromator, compensating (automatic) divergent silt, and automatic sample changer. All runs were performed at 45kV and 35mA using Cuka radiation and were made in the step-mode at the speed of 0.05° 2θ per step (equivalent to 0.5° 2θ per minute). Output from the XRD was directly captured by a computer (HP1000) equipped with software programs to identify peak positions and calculate integrated peak area intensities. Minerals present were identified by computer search for three peaks (Table A.1), confirmed manually by comparing with standards. For all the minerals identified, the diagnostic peak area intensities were multiplied by their respective intensity factors (Table A.1) to compensate for differences in "diffracting power" of different minerals. These modified intensities

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MODSTD T=00004 IS ON CR P0   USING 00012 BLKS R=0000

0001        TABLE AI   2@ AND INTENSITY FACTORS (RELATIVE TO QUARTZ) FOR
0002                   THE MATCH PROGRAM. NAME ABBREVIATIONS IN BRACKETS.
0003
0004                             UPPER      LOWER     INTENSITY
0005                              2@1        2@1       FACTORS       2@2        2@3
0006
0007   CA-SMECTITE(CS)       5.20       4.70        4.50      19.73      17.71
0008   VERMICULITE(VE)       5.72       5.44        3.70      60.50      37.16
0009   NA-SMECTITE(NS)       7.30       6.60        7.5       19.73      17.71
0010   SEPIOLITE(SE)         7.40       7.00        2.00      35.06      20.61
0011   PALYGORSKITE(PA)      8.50       8.20        9.20      19.86      20.85
0012   ILLITE   (IL)         9.10       8.70       11.50      19.91      26.53
0013   KAOLINITE(KA)        12.60      12.20        4.00      24.87      62.32
0014   CHLORITE(CH)          5.80       6.20        2.6       18.80      35.93
0015   PHILIPSITE(PH)       18.00      17.50       17.00      27.97      21.52
0016   AMPHIBOLE(Am)        10.70      10.30        2.50      28.80      27.35
0017   ANALCITE(AN)         16.20      15.60        1.79      25.98      30.51
0018   QUARTZ(QU)           26.95      26.45        1.00      20.85      50.13
0019   K-FELDSPAR(KF)       27.79      27.35        4.30      21.05      24.05
0020   ALBITE(AL)           28.15      27.80        2.8       23.54      13.86
0021   PYROXENE(PX)         14.00      13.50        3.00      27.75      29.78
0022   APATITE(AP)          32.15      31.90        3.10      32.93      39.89
0023   BARITE(BA)           29.00      28.65        3.10      39.35      43.08
0024   CALCITE(CA)          29.60      29.25        0.90      39.35      43.08
0025   DOLOMITE(DC)         31.15      30.80        1.53      41.23      51.03
0026   RHODOCROCITE(RH)     31.50      31.26        1.10      34.32      51.96
0027   SIDERITE(SI)         32.40      31.90        1.15      52.93      24.80
0028   MAGNESITE(MA)        32.84      32.48        1.50      43.08      53.94
0029   ARAGONITE(AR)        46.00      45.65        9.30      26.21      27.28
0030   BARITE(BA)           29.00      28.65        6.50      25.90      42.65
0031   GYPSUM(GY)           11.80      11.30        0.40      29.29      20.81
0032   ANHYDRITE(AH)        25.70      25.30        0.90      31.39      38.65
0033   HALITE(HA)           45.65      45.30        2.00      31.73      56.46
0034   HEMATITE(HE)         33.40      33.00        2.10      54.29      35.78
0035   MAGNETITE(MT)        35.70      35.30        4.50      62.32      30.09
0036   GOETHITE(GO)         37.05      36.45        7.00      21.26      33.31
0037   PYRITE(PY)           33.15      32.95        3.50      56.30      37.16
```

then normalized to calculate the abundances of each mineral present. Such abundances were shown to have an accuracy of 0.4% by analyzing mixtures of standards (Cook et al 1973). However, the results from this study must be treated as semi-quantitative due to a number of uncertainties involved, such as variable composition of solid solutions, crystallinity, preferred orientation, overlapping peaks, presence of amorphous material and phases not identified.

Note that for most of the bulk samples, smectite and mixed layer clays or illite and mixed layer clays cannot be distinguished. Hence they are designated as smectite/mixed layer (SME/M.L.) or illite/mixed layer (ILL/M.L.). For the clay fractions, these phases can usually be identified after the glycolation and heating and also the higher proportion present.

4. Results

General Statement

The majority minerals identified in the sediments studied include quartz, feldspar, illite/mixed layer (ILL/M.L.) clays, smectite/mixed layer (SME/M.L.) clays, dolomite, calcite and sometimes also variable but usually small amounts of chlorite, siderite, pyrite, analcite and pyroxene. Some samples also contain other minor phases such as iron oxides and hydroxides, but these are not included since they are not important to this study.

For most samples, only the bulk was analyzed, rendering distinction between smectite and mixed layer clays, and illite and mixed layer clays impossible. Hence in the reported data tables and in the report itself, illite or smectite will always imply the possible presence of mixed layer clays. For each set of data, the mean standard deviation and % error (s.d./mean X100), and the ratios illite/kaolinite, quartz/feldspar and calcite/dolomite are computed.

Discussion of the analytical results by drill hole and geographical area follows. An attempt is made to relate the various suites of results amongst themselves and also to Macauley's subdivisions.

Petro-Canada Dover No. 1

The purpose of this hole was to explore the lower zones of the Albert Formation, reported as lacking in oil shales. In comparison with the Frederick Brook facies intersected in Petro-Canada Dover No. 2, the strata are generally considerably less dolomitic and it is interesting to note that they are no more calcitic. (Table 1) It appears that the dolomitic bands are here considerably more frequently interbedded with carbonate-poor bands. Feldspar occurs in somewhat greater abundance here in compensation for the reduction in dolomite. No significant trends are apparent for correlation purposes. A plot of the abundance of the various constituent minerals appears as Figure 7.

Petro-Canada Dover No. 2

Petro-Canada No. 2 penetrated both Frederick Brook and Dawson Settlement facies but the sampling was confined to the Frederick Brook facies for possible correlation with Macauley's zones in the Albert Mines area. (Macauley, 1982)

Three sandstone units were encountered in the hole. They are located in Table 2 and described as Sands 1, 2 and 3. These sandstones are useful in subdividing the Frederick Brook facies for mineralogical description and in fact appear to be boundaries for mineralogical units.

Unit 1, (Table 2) above Sand 1 is conspicuously high in analcite and low in calcite compared with Unit 2, below Sand 1.

The section between Sand 1 and Sand 2 subdivides conveniently into Units 2A and 2B, based again on analcite and calcite content. Unit 2A is low in analcite and high in calcite while Unit 2B has the opposite relationship. In fact, there is virtually no calcite in the unit, which is a parallel with the zones below the Albert Mines Zone of Macauley. The significant analcite content, however, would suggest that Unit 2B has more in common with Macauley's Clay Marlstone Zone than with his more extensive Dolomite Marlstone Zone.

Below Unit 2B, the departure from Macauley's pattern is obvious as calcite makes it reappearance. Unit 3 is a moderate calcite/low analcite zone and Unit 4 has high calcite and analcite.

See also the mineralogy log which appears as Figure 8.

Atlantic Richfield Dover No. 1A

The few samples obtained for this study from the Atlantic Richfield hole are almost all from the zones described as Unit 2B and 3 in Petro-Canada Dover No. 2. Again (Table 3) there is a significant switch of calcite and analcite proportions although here the sandstone does not mark the boundary. Macauley (1982) shows these samples as belonging to the Clay Marlstone and Dolomite Marlstone Zones, but he obviously has some doubts, as evidence by the question marks on his Figure 5.

Petro-Canada Boudreau No. 1

The two zones analyzed from this core are located as shown in Figure 8. The lithology of these zones is fairly typical Dolomite Marlstone but the analcite content of the upper zone (Table 4) disagrees with Macauley's definition, although the lack of calcite is most noticeable. Calcite is relatively abundant in the lower zone where the analcite content is low.

See also the mineralogy log which appears as Figure 9.

Atlantic Richfield Boudreau No. 1

A series of eight samples was taken from the core for analysis (Table 10). The majority are calcite-free and generally similar to the upper set of samples in Petro-Canada Boudreau No. 1. According to Macauley (1982, Figure 5) these samples represent all facies from Hiram Brook to Dolomite Marlstone but it is hard to see how the results fit in with his criteria.

Summary of Core Data

The mineralogical characteristics of the three Petro-Canada holes are summarized in Table 5.

Downing Creek Area

The surface samples taken from the valley of Downing Creek represent Frederick Brook, Dawson Settlement and Downing Creek facies. The mineralogical content summarized in Table 6 shows general agreement with the appropriate portions of Dover No. 1. Analcite and feldspar are less abundant here which could result from weathering. No significant trends are apparent for subdivision.

Boyd Creek Area

The samples from Boyd Creek represent the strata above the Frederick Brook facies. By projection from Imperial Gautreau No. 1 (Cross-section BB') these samples may be assumed to represent Hiram Brook facies and the evaporite sub-facies within it. The Hiram Brook facies is virtually dolomite-free and the three samples high in dolomite in Table 7 can be assigned to the evaporite sub-facies. In the Hiram Brook facies, quartz is dominant over feldspar and analcite is almost unknown.

LeBlanc Creek Area

The three samples obtained from LeBlanc Creek show no consistency and no conclusions are drawn from them. The results are shown in Table 8.

Taylor Village Area

The Taylor Village shales belong to the Frederick Brook facies. There are no features sufficiently diagnostic to correlate them with the Dover area. (Table 9) Dolomite is, predictably, present in substantial quantities and feldspar predominates over quartz. Analcite is present, in the amount of 1%. These shales probably belong to Macauley's Dolomite Marlstone zone.

Bill's Creek

Only three samples were analyzed, two of which are typical dolomitic "oil shales" similar to the core material in the Boudreau holes, with low analcite. The third is calcite-rich. The results appear in Table 11.

5. Conclusion

It is concluded from the above that the use of mineralogy to subdivide the Frederick Brook facies in the St. Joseph project area according to the Macauley scheme has not been demonstrated to be practicable. With sufficient additional drilling it is probable that a method of correlation suited to local areas can be devised.

KEY TO THE MINERALOGY LOGS

1. SUM: plots of sums of:

   a) quartz + feldspar (SIL)

   b) all the clays present (CLA)

   c) all the carbonates present (CAR)

2. CLAYS: plots of the cumulative abundances of the various clay minerals present. Names of the clays are represented by the first 3 letters, eg.

   ILL = illite

   KAO = kaolinite (+ illite)

   CHL = chlorite (+ illite + kaolinite)

3. CARBONATES: similar to 2 for the various carbonates.

FIGURE 7

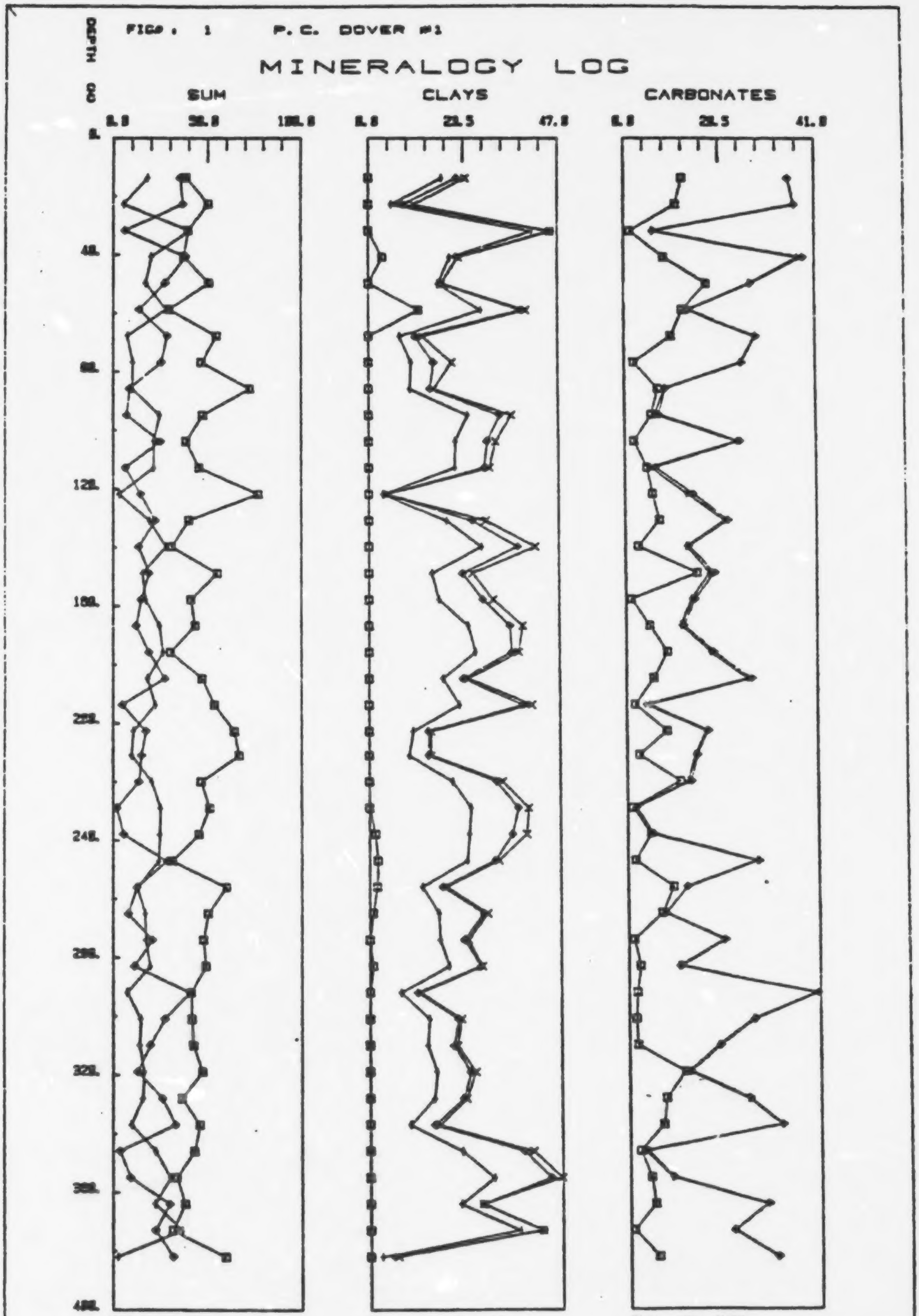

FIG# : 1 P. C. DOVER #1
MINERALOGY LOG
DEPTH (ft)
SUM
CLAYS
CARBONATES
0.0
50.0
100.0
0.0
23.5
47.0
0.0
20.5
41.0
0.
40.
80.
120.
160.
200.
240.
280.
320.
360.
400.
□SIL +CLA ◇CAR
□SME +ILL ◇KAO X
□CAL +DOL

FIGURE 8

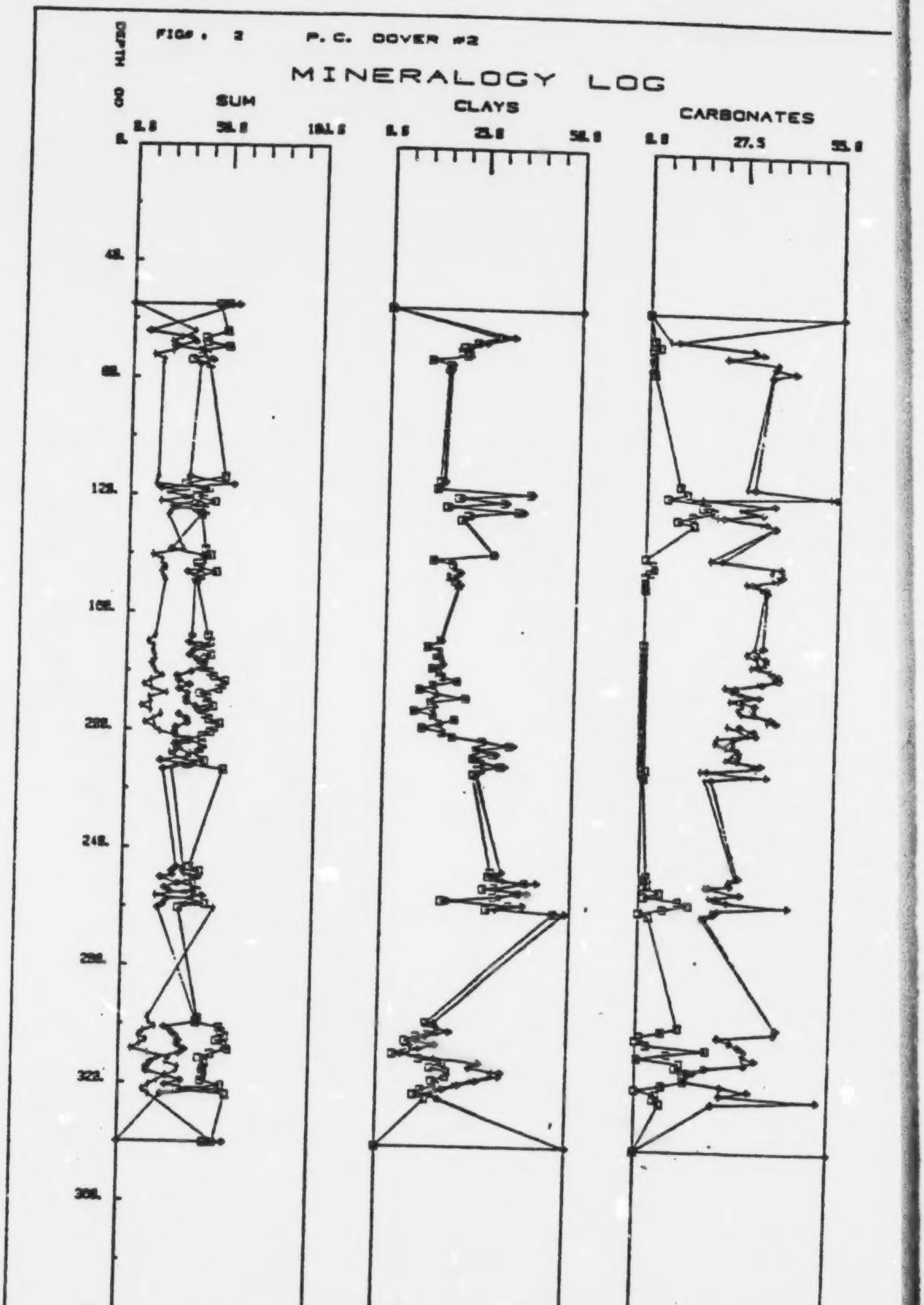
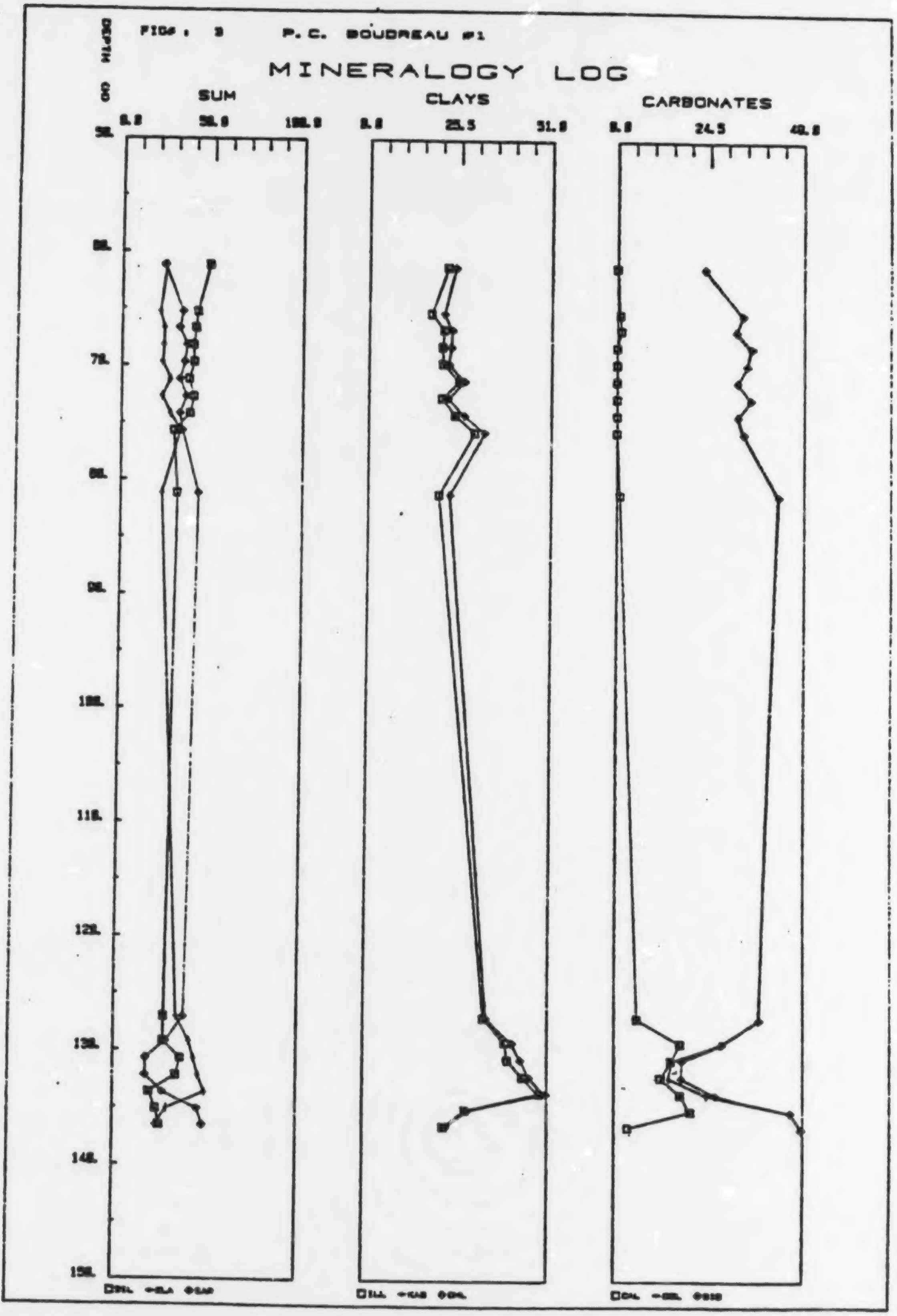

DEPTH OOO
FIG# . 2
P. C. DOVER #2
MINERALOGY LOG
SUM
CLAYS
CARBONATES
0.
0.0
50.0
100.0
0.0
25.0
50.0
0.0
27.5
55.0
40.
80.
120.
160.
200.
240.
280.
320.
360.
400.

FIGURE 9


FID# : 3
P. C. BOUDREAU #1
MINERALOGY LOG
DEPTH CHD
SUM
CLAYS
CARBONATES
0.0
50.0
100.0
0.0
25.5
51.0
0.0
24.5
49.0
50.
60.
70.
80.
90.
100.
110.
120.
130.
140.
150.
□QTZ +CLA ◇CAR
□ILL +KAO ◇CHL
□CAL +DOL ◇SID

DATE: DEC.,1982

Table 1.

PETRO CANADA ST. JOSEPH OIL SHALE PROJECT,BULKS

PROJECT.#: A212827
USER: COAL

DOVER #1

DEPTH	SME/M.	ILL/M.	KAOLIN	CHLORI	ANALCI	PYROXE	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE	
X-FACTOR	7.50	11.50	4.00	2.60	1.79	3.00	1.00	2.80	.90	1.53	1.10	3.50	
13.00	9.00	10.08	3.72	2.23	0.00	.56	15.79	22.81	12.53	22.85	0.00	1.45	Dawson Settlement Facies
22.00	0.00	5.55	2.74	3.00	0.00	0.00	19.09	31.22	11.07	25.59	0.00	1.74	
31.00	0.00	40.43	4.69	0.00	5.10	0.00	14.76	24.92	1.34	4.54	.33	3.89	
40.00	3.38	16.71	1.00	.49	0.00	0.00	16.66	20.70	8.58	20.76	1.12	1.00	
49.00	0.00	17.15	.88	0.00	2.10	.03	19.24	31.34	17.75	9.30	.30	1.03	
50.00	12.29	15.50	9.96	1.21	15.52	1.06	13.74	15.77	12.49	1.14	.13	1.20	
67.00	0.00	7.59	3.78	1.95	0.00	0.00	18.73	35.93	9.95	10.32	.17	3.57	
76.00	0.00	10.42	5.62	4.59	3.73	0.00	14.31	32.33	2.04	23.09	.28	3.59	
05.00	0.00	10.17	4.97	.93	0.00	2.23	20.92	51.27	7.09	1.35	.25	.81	
94.00	0.00	24.43	7.95	2.87	5.70	1.08	16.40	30.90	5.71	.76	.77	3.43	
103.00	0.00	21.40	7.86	2.11	5.30	0.00	13.62	24.01	2.02	22.24	.63	0.00	Downing Creek Facies
112.00	0.00	21.20	7.19	1.36	8.53	1.10	19.50	25.91	4.75	.59	1.11	8.68	
121.00	0.00	3.26	.70	.53	0.00	2.75	23.14	53.75	5.89	7.23	1.34	1.42	
130.00	0.00	19.13	6.32	3.45	5.10	0.00	15.06	24.95	7.30	14.09	.76	3.85	
139.00	0.00	27.79	8.80	4.41	8.80	0.00	12.64	18.20	2.77	10.21	.56	5.74	
140.00	0.00	15.48	7.55	2.55	.42	0.00	20.38	34.65	15.31	2.62	1.05	0.00	
157.00	0.00	17.10	10.88	2.56	8.56	0.00	10.56	22.59	1.20	12.76	.81	4.92	
166.00	0.00	24.40	10.24	3.13	4.56	0.00	17.29	25.98	5.08	6.61	.59	2.11	
175.00	0.00	26.21	8.85	1.79	8.26	0.00	13.27	16.96	8.79	9.27	.76	5.85	
104.00	0.00	18.12	4.94	1.54	0.00	0.00	15.09	31.03	5.90	20.39	.85	1.33	
193.00	0.00	22.15	15.64	2.23	0.00	0.00	14.40	39.18	1.85	2.89	.97	1.50	
202.00	0.00	10.70	3.03	.64	0.00	2.26	19.02	45.01	8.59	8.37	.29	1.29	
211.00	0.00	9.72	4.02	.64	.24	1.66	15.26	51.35	2.71	11.80	.48	1.30	
220.00	0.00	20.36	10.74	1.56	4.27	1.11	13.79	32.71	11.36	1.62	.68	1.08	
229.00	0.00	24.88	11.56	2.63	4.88	1.20	17.99	32.96	1.13	.54	.36	1.88	
238.00	1.43	23.08	10.51	3.56	6.59	0.00	20.23	25.07	5.00	0.00	.61	3.96	
247.00	2.02	21.94	6.82	.94	4.10	0.00	11.46	19.82	1.69	26.25	.31	4.56	
256.00	1.00	11.05	5.00	1.00	4.13	1.07	11.00	40.83	9.74	2.87	0.00	2.63	
265.00	.79	16.14	10.97	1.03	7.23	1.27	7.30	42.07	7.33	.71	0.00	4.36	Dawson Settlement Facies (Lower)
274.00	0.00	17.22	5.94	1.03	2.75	1.31	19.73	27.98	1.24	19.34	.10	3.36	
283.00	.80	10.57	7.05	.35	6.21	.72	11.91	37.00	2.55	8.17	.51	5.28	
292.00	0.00	7.56	3.97	.91	1.65	1.00	7.76	33.39	1.82	30.50	0.00	2.64	
301.00	0.00	14.47	7.15	.76	3.75	1.13	10.66	30.99	1.59	25.20	.39	3.91	
310.00	0.00	14.09	6.45	.84	4.34	.75	12.04	30.45	1.08	17.21	.40	11.55	
319.00	0.00	16.30	8.24	1.29	5.44	1.75	11.40	35.88	11.88	.56	.56	6.70	
328.00	0.00	15.74	7.13	.68	6.15	.46	14.04	21.65	7.91	17.64	.47	7.32	
337.00	0.00	9.80	5.88	1.37	1.50	1.86	10.10	27.00	7.33	25.35	.17	.76	
346.00	0.00	22.40	15.05	2.33	6.92	0.00	16.03	27.12	2.25	.90	.65	6.28	
355.00	0.00	30.26	13.80	2.62	6.54	0.00	12.76	20.97	4.56	4.28	.45	3.67	
364.00	0.00	22.12	5.40	0.00	2.34	0.00	19.13	18.97	5.43	24.16	.14	2.31	
373.00	0.00	36.49	5.49	0.00	1.80	0.00	15.34	16.29	.84	21.50	0.00	2.25	
302.00	0.00	2.75	2.94	.93	.67	0.00	35.64	23.91	6.15	25.42	.15	1.43	

STATISTICS

	SME/M.	ILL/M.	KAOLIN	CHLORI	ANALCI	PYROXE	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
MEAN	3.22	17.01	7.02	1.79	4.95	1.37	16.07	30.15	6.01	12.70	.54	3.43
S.DEV.	4.10	8.83	3.52	1.11	3.06	.61	4.72	9.80	4.28	10.35	[illegible]	[illegible]
ERROR	127.36	15.10	[illegible]	[illegible]	[illegible]							

Table 1(cont'd) PETRO CANADA ST. JOSEPH OIL SHALE PROJECT,BULK

DOVER #1

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	QU/FE	CA/DO
13.00	4.87	.69	.55
22.00	.70	1.71	.74
31.00	3.00	1.66	.50
40.00	3.23	2.25	.50
49.00	6.75	1.72	3.25
58.00	.54	2.44	18.58
67.00	.70	1.46	.92
76.00	.65	1.24	.15
85.00	.71	1.14	8.91
94.00	1.07	1.49	12.70
103.00	.95	1.54	.15
112.00	1.03	2.11	13.73
121.00	1.62	1.21	1.39
130.00	1.05	1.69	.88
139.00	1.09	1.94	.46
148.00	.71	1.65	9.94
157.00	.55	2.30	.16
166.00	.83	1.86	1.31
175.00	1.03	2.19	1.61
184.00	1.28	1.43	.49
193.00	.49	1.03	1.50
202.00	.97	1.18	1.74
211.00	.70	.83	.39
220.00	.66	1.18	11.95
229.00	.75	1.53	3.57
238.00	.76	2.26	0.00
247.00	1.12	1.62	.11
256.00	.77	.63	5.78
265.00	.51	.48	17.57
274.00	1.01	1.97	.11
283.00	.82	.90	.53
292.00	.66	.65	.08
301.00	.70	.96	.11
310.00	.76	1.11	.19
319.00	.69	.89	36.12
328.00	.77	1.92	.76
337.00	.58	1.82	.49
346.00	.52	1.66	4.25
355.00	.76	1.70	1.81
364.00	1.43	2.82	.38
373.00	2.31	2.64	.07
382.00	.33	4.17	.41

STATISTICS

MEAN	1.20	1.61	4.02
ST.DEV.	1.22	.69	7.18
% ERROR	101.47	43.12	178.52
#SAMPLE	42	42	41

DATE: DEC.,1982 Table 2. PETRO CANADA ST.JOSEPH OIL SHALE PROJECT

PROJECT.#: A212027
USER: COAL

DOVER #2.

DEPTH	ILL/M.	KAOLIN	CHLORI	ANALCI	PYROXE	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE	
X-FACTOR	11.50	4.00	2.60	1.79	3.00	1.00	2.00	.90	1.53	1.10	3.50	
64.00	20.59	3.71	.19	4.08	1.45	20.67	20.57	1.50	4.34	2.35	4.55	
66.00	22.56	2.50	.10	3.14	.70	16.12	21.93	3.00	26.64	.27	2.80	
67.00	19.08	.92	.60	3.03	.60	17.15	21.68	.08	31.31	.34	4.41	
69.00	18.36	2.13	0.00	2.29	.60	24.84	25.33	1.10	21.01	.33	3.93	Unit 1.
70.00	19.66	.92	0.00	3.39	1.05	16.67	19.06	.74	35.43	.40	2.67	
72.00	10.72	.13	0.00	4.92	.24	17.08	21.65	1.27	34.00	.87	9.12	
73.00	15.39	.66	0.00	4.74	.74	11.54	19.62	.76	40.25	.56	5.74	
75.00	15.15	.31	.37	3.71	1.08	17.36	22.08	1.64	33.24	.41	3.84	
113.00	13.61	.69	.53	.00	.05	19.93	29.91	9.54	19.19	2.20	2.65	Sand 1
116.00	12.87	.33	.30	.24	1.20	8.64	20.20	11.47	40.96	1.61	2.02	
117.00	37.56	.26	.31	.12	.78	19.67	21.87	6.00	7.43	2.57	3.43	
119.00	10.34	1.24	.00	.08	.88	12.74	25.92	10.42	16.75	1.26	4.28	
120.00	30.63	.85	0.00	.17	.48	13.68	21.37	16.13	10.80	1.08	4.01	
122.00	15.44	.51	.30	.40	.72	16.53	28.12	19.57	11.73	1.96	4.63	Unit 2A
123.00	34.35	1.14	.47	.16	.40	16.98	20.07	13.16	7.24	1.84	4.18	
125.00	20.83	.88	.39	.15	.86	14.08	24.71	8.83	23.83	1.51	3.12	
126.00	19.25	.76	0.00	.52	1.05	14.39	23.60	13.61	22.67	.64	3.51	
138.00	28.25	0.00	.29	2.98	.03	14.27	25.93	0.00	18.43	3.59	5.42	
140.00	12.14	.19	0.00	.77	2.83	19.30	23.07	2.04	34.50	1.97	2.30	
142.00	17.05	.18	.11	.79	2.29	17.09	21.70	2.35	33.47	2.86	2.11	
143.00	17.24	0.00	0.00	1.82	2.02	15.54	20.35	1.35	36.46	1.22	3.99	
144.00	18.77	.54	0.00	1.39	.57	13.82	23.16	0.00	36.30	1.17	4.20	
146.00	16.67	.17	.07	.96	1.24	13.12	33.05	0.00	29.02	1.73	3.96	
147.00	17.90	0.00	.50	3.01	.86	15.89	22.21	0.00	32.86	1.74	5.02	
149.00	10.80	.19	.24	5.77	.61	13.89	22.06	.07	34.16	.67	3.54	
168.00	14.40	.36	0.00	3.04	2.28	16.01	26.75	0.00	31.81	2.20	2.39	
170.00	11.00	0.00	.42	5.17	1.01	17.05	26.98	0.00	29.53	2.84	5.93	
171.00	14.05	0.00	.15	5.51	1.47	14.65	23.46	0.00	32.11	2.67	5.94	
173.00	13.50	0.00	.12	5.72	1.56	15.45	26.62	0.00	32.69	2.27	2.08	Unit 2B
174.00	14.37	0.00	.18	4.08	1.22	14.56	29.80	0.00	30.89	2.15	1.97	
176.00	14.77	.12	.40	4.60	.78	15.35	25.73	0.00	35.53	1.13	1.61	
177.00	12.45	.18	0.00	4.31	2.21	15.06	25.59	0.00	36.67	1.95	1.58	
170.00	14.00	.13	.16	3.99	.57	17.53	22.93	0.00	37.64	1.01	2.05	
180.00	15.10	0.00	.08	4.30	.90	15.77	28.29	0.00	32.74	1.25	1.57	
181.00	18.95	0.00	.10	4.05	1.95	11.64	34.76	0.00	23.36	3.22	1.16	
183.00	12.76	.16	.20	2.94	1.64	11.24	40.90	0.00	25.52	2.09	2.40	
104.00	9.27	0.00	.06	5.65	1.04	20.70	29.97	0.00	30.46	2.85	0.00	
106.00	13.34	.12	.23	6.78	1.37	23.38	25.37	0.00	25.01	2.86	1.54	
107.00	21.27	.11	.15	7.41	0.00	16.90	22.02	0.00	28.84	3.29	0.00	
109.00	12.16	0.00	.29	5.11	1.00	17.08	26.16	0.00	27.24	4.36	5.08	
190.00	12.63	.56	.22	4.64	1.90	13.42	20.93	0.00	28.30	3.55	6.84	
191.00	7.92	.11	0.00	3.11	.70	15.60	30.63	0.00	35.14	1.49	5.30	
193.00	12.89	0.00	.08	3.06	1.37	15.77	24.53	0.00	35.70	2.30	4.29	
194.00	18.40	0.00	0.00	4.71	2.08	11.94	29.91	0.00	24.49	3.49	4.90	
196.00	14.39	.25	.12	5.45	1.67	9.82	34.21	0.00	28.12	3.81	2.16	
197.00	9.98	0.00	.17	1.79	3.12	15.77	33.02	0.00	30.43	1.94	2.99	
199.00	15.36	0.00	0.00	4.22	2.53	13.14	33.66	0.00	21.58	4.74	4.77	
200.00	18.04	0.00	.16	4.44	1.97	14.24	30.62	0.00	20.88	4.04	4.08	
202.00	26.23	.79	0.00	1.66	1.12	15.60	24.75	0.00	24.13	2.39	3.25	
203.00	33.40	.91	.16	1.29	.40	14.63	17.91	0.00	26.79	1.03	3.49	
205.00	24.69	.49	.10	1.61	1.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

DATE: DEC.,1982 Table 2(cont'd) PETRO CANADA ST.JOSEPH OIL SHALE PROJECT

PROJECT.#: A212027 DOVER #2.
USER: COAL

DEPTH	ILL/M.	KAOLIN	CHLORI	ANALCI	PYROXE	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE	
X-FACTOR	11.50	4.00	2.60	1.79	3.00	1.00	2.80	.90	1.53	1.10	3.50	
207.00	23.70	0.00	.15	.70	.40	16.70	21.70	0.00	32.49	1.45	2.54	
209.00	25.11	1.42	.29	1.19	.52	19.41	17.62	0.00	30.35	2.42	1.67	
210.00	31.06	1.11	.17	1.34	1.07	21.33	20.66	1.16	15.77	1.90	4.43	
211.00	25.14	1.67	0.00	1.00	.66	16.98	15.52	.12	31.56	3.88	3.46	
213.00	23.82	.09	.22	.72	1.33	20.87	22.92	.70	17.59	1.91	1.02	Sand 2
246.00	29.35	2.60	.18	.08	.94	14.37	20.69	2.00	25.38	.78	3.61	
247.00	28.77	1.82	.18	.13	.77	18.51	22.01	1.57	23.92	.33	1.99	
249.00	30.44	1.99	.13	.22	.62	17.69	20.44	2.39	22.33	1.28	2.47	
250.00	30.21	2.60	.31	.16	1.22	15.84	18.94	1.22	17.56	1.18	2.75	
252.00	27.30	3.09	.73	.14	.48	16.61	20.48	5.81	21.67	1.29	2.33	
253.00	36.54	2.20	0.00	.09	.86	16.30	19.10	1.37	18.64	2.23	2.68	
254.00	30.08	1.63	0.00	.11	1.09	19.11	20.32	11.12	10.59	3.48	2.49	
256.00	15.91	1.55	.18	.09	.76	13.46	22.25	14.00	27.87	.33	3.60	
257.00	34.18	3.12	.44	.14	.70	16.45	19.55	6.83	14.16	1.70	2.73	
259.00	28.34	2.53	0.00	.12	.81	18.58	25.11	0.00	20.73	.81	2.98	
260.00	45.75	2.56	.32	.09	.76	14.04	15.67	2.90	14.87	1.11	1.92	
298.00	12.65	2.04	.12	.34	.96	20.37	20.89	11.89	27.75	.25	2.73	Unit 3
299.00	13.29	2.14	0.00	.38	.85	16.90	23.17	7.12	31.73	.47	3.95	
301.00	15.26	3.32	0.00	.23	1.49	17.04	35.30	1.09	22.10	.24	3.93	
302.00	10.22	2.13	.46	.24	1.42	17.31	36.40	0.00	26.80	.10	4.92	
304.00	7.23	2.87	.29	.38	1.85	16.46	39.19	2.97	26.47	0.00	2.29	
305.00	9.63	4.27	1.11	.32	.94	19.88	31.22	20.08	10.58	.42	1.55	
307.00	7.74	2.92	.26	.23	1.09	15.42	39.00	8.91	21.43	.40	1.82	
308.00	4.19	1.92	.11	.18	1.57	15.17	41.79	.46	33.41	.22	.97	
310.00	11.10	3.86	.11	.91	1.78	13.36	34.82	12.56	18.23	.58	2.70	Sand 3
311.00	17.39	9.24	.33	4.42	1.24	13.04	29.00	11.45	7.70	.99	5.19	
313.00	14.00	10.30	0.00	6.89	1.07	13.78	31.57	14.77	0.00	1.83	5.70	
314.00	10.41	12.54	1.95	6.57	2.20	14.11	29.75	13.72	0.00	.75	0.00	
316.00	10.12	11.87	2.46	6.56	1.69	14.46	30.37	13.94	0.00	.53	0.00	
317.90	14.54	10.28	1.48	3.08	1.58	15.67	20.75	7.62	16.84	.15	0.00	
319.00	15.91	4.33	1.12	1.05	1.80	11.99	31.39	0.00	32.21	.20	0.00	Unit 4
320.00	11.61	4.20	1.63	.98	1.68	15.29	38.43	6.05	18.08	.24	1.81	
322.00	9.78	2.75	1.53	2.57	.54	10.27	20.90	5.27	46.16	.24	0.00	
323.00	12.66	2.81	.93	1.21	1.11	15.43	40.68	7.11	14.78	.16	3.11	

STATISTICS

MEAN	18.97	2.16	.41	2.37	1.19	16.03	26.12	6.59	25.63	1.65	3.3
ST.DEV.	8.32	2.74	.48	2.18	.60	3.15	6.18	5.90	8.71	1.18	1.4
% ERROR	43.07	126.57	117.64	91.72	50.06	19.63	23.66	89.50	33.99	71.52	44.23
#SAMPLE	86	69	64	86	85	86	86	50	83	85	7

PETRO CANADA ST.JOSEPH OIL SHALE PROJECT

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	QU/FE	CA/DO
64.00	7.71	.72	.35
66.00	8.75	.73	.11
67.00	20.70	.79	.03
69.00	8.63	.98	.06
70.00	21.47	.87	.02
72.00	83.38	.79	.04
73.00	23.48	.59	.02
75.00	48.30	.76	.05
113.00	19.60	.67	.50
116.00	39.10	.43	.28
117.00	143.75	.90	.81
119.00	14.81	.49	1.10
120.00	35.94	.64	1.49
122.00	29.98	.59	1.67
123.00	30.26	.85	1.82
125.00	23.72	.60	.37
126.00	25.43	.61	.60
138.00	0.00	.55	0.00
140.00	63.25	.81	.06
142.00	96.79	.79	.07
143.00	0.00	.76	.04
144.00	34.50	.60	0.00
146.00	100.63	.40	0.00
147.00	0.00	.72	0.00
149.00	100.62	.63	.00
168.00	40.25	.60	0.00
170.00	0.00	.63	0.00
171.00	0.00	.62	0.00
173.00	0.00	.58	0.00
174.00	0.00	.49	0.00
176.00	120.75	.60	0.00
177.00	69.00	.59	0.00
178.00	110.69	.76	0.00
180.00	0.00	.56	0.00
181.00	0.00	.33	0.00
183.00	79.54	.27	0.00
184.00	0.00	.69	0.00
186.00	113.56	.92	0.00
187.00	188.31	.77	0.00
189.00	0.00	.65	0.00
190.00	22.42	.46	0.00
191.00	71.88	.51	0.00
193.00	0.00	.64	0.00
194.00	0.00	.40	0.00
196.00	58.22	.29	0.00
197.00	0.00	.47	0.00
199.00	0.00	.39	0.00
200.00	0.00	.47	0.00
202.00	33.06	.63	0.00
203.00	36.62	.82	0.00
205.00	50.03	.55	0.00
206.00	25.88	.95	0.00

Table 2 (cont'd)

207.00	0.00	.77	0.00
209.00	17.65	1.10	0.00
210.00	28.07	1.03	.07
211.00	15.09	1.09	.00
213.00	26.77	1.26	.04
246.00	11.29	.69	.08
247.00	15.81	.84	.07
249.00	15.29	.87	.11
250.00	14.71	.84	.07
252.00	8.87	.81	.27
253.00	16.62	.85	.07
254.00	18.42	.94	1.05
256.00	10.25	.61	.50
257.00	10.97	.84	.48
259.00	11.21	.74	0.00
260.00	17.84	.90	.20
298.00	6.20	.98	.43
299.00	6.20	.73	.22
301.00	4.60	.48	.05
302.00	4.79	.48	0.00
304.00	2.52	.42	.11
305.00	2.26	.64	1.90
307.00	2.65	.39	.42
308.00	2.18	.36	.01
310.00	2.88	.38	.69
311.00	1.88	.45	1.49
313.00	1.35	.44	0.00
314.00	1.47	.47	0.00
316.00	1.53	.48	0.00
317.00	1.41	.55	.45
319.00	3.67	.38	0.00
320.00	2.76	.40	.33
322.00	3.56	.49	.11
323.00	4.50	.38	.48

Table 2(cont'd)

DATE: DEC.,1982 Table 3 ARCO DOVER 1A OIL SHALE

PROJECT.#: A212027
USER: COAL

BULK

DEPTH	ILL/M.	KAOLIN	CHLORI	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE	
X-FACTOR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
62.00	41.57	1.66	2.93	0.00	26.10	13.99	7.99	0.00	5.33	.43	sand
91.40	12.96	.47	.24	3.13	24.77	20.29	0.00	27.12	1.42	9.60	
96.00	9.95	0.00	0.00	14.61	14.87	21.34	0.00	31.29	2.94	5.00	
147.80	31.72	1.49	.99	0.00	32.77	23.50	2.73	5.61	1.20	0.00	
164.60	51.15	1.62	3.27	.01	13.30	18.30	7.25	.77	3.11	1.22	
185.00	38.50	1.95	.61	.01	20.64	14.30	15.30	4.30	3.40	1.00	
228.60	3.88	.32	1.88	0.00	21.12	15.00	17.58	38.91	.01	1.30	

STATISTICS

MEAN	27.10	1.25	1.65	4.44	21.94	18.10	10.17	18.00	2.49	3.09
T.DEV.	18.13	.68	1.25	6.94	6.70	3.77	6.12	16.34	1.75	3.58
ERROR	66.89	54.49	75.63	156.27	30.55	20.84	60.17	90.79	70.47	115.86
SAMPLE	7	6	6	4	7	7	5	6	7	6

DATE: DEC.,1982 Table 4 PETRO CANADA ST.JOSEPH OIL SHALE PROJECT

PROJECT.#: A212027 PETRO-CANADA BOUDREAU,#1
USER: COAL

DEPTH	ILL/M.	KAOLIN	CHLORI	ANALCI	PYROXE	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	11.50	4.00	2.60	1.79	3.00	1.00	2.80	.90	1.53	1.10	3.50
61.00	22.04	2.02	.13	1.29	1.36	16.64	31.46	0.00	22.90	.22	1.94
65.00	17.45	3.29	.25	1.37	.75	16.51	24.79	.80	32.14	.15	2.49
66.00	21.03	1.97	.22	2.39	1.31	14.70	25.72	1.01	30.22	.20	1.23
68.00	20.58	2.23	.21	1.04	.60	15.96	23.20	0.00	34.94	.51	.74
69.00	20.73	1.47	.21	.24	1.35	16.62	23.06	0.00	34.10	.11	2.10
71.00	25.26	1.24	.29	.67	1.38	14.87	22.10	0.00	31.67	.15	2.39
72.00	20.47	1.71	0.00	.99	.51	16.63	22.93	0.00	35.10	.16	1.50
74.00	24.19	2.44	.11	1.83	.91	16.27	21.31	0.00	31.68	.29	.97
75.00	29.62	2.73	0.00	.38	2.45	17.20	11.79	0.00	33.04	.45	2.33
81.00	19.81	2.79	.30	1.25	.56	16.62	14.43	.91	41.22	.38	1.74
127.00	33.30	.64	.10	.12	.16	16.93	10.20	6.10	31.61	.18	.65
129.00	39.42	1.65	.44	.10	.21	16.33	10.63	17.31	10.45	.66	2.79
130.00	40.19	3.57	0.00	.05	.54	20.24	16.32	14.91	.14	2.70	1.35
132.00	44.38	1.84	0.00	.07	.51	18.35	15.88	12.27	2.03	3.25	1.42
133.00	48.65	1.11	.94	.09	.69	11.46	8.30	17.36	7.03	2.27	2.11
135.00	28.40	.78	0.00	.22	0.00	13.32	10.10	19.93	25.81	.09	1.36
136.00	22.37	.65	.07	.12	.94	14.94	10.40	3.78	44.87	0.00	1.86

STATISTICS

MEAN	28.11	1.89	.27	.72	.89	16.09	17.80	9.44	26.41	.73	1.70
ST.DEV.	9.64	.88	.23	.72	.58	1.93	6.98	7.70	13.39	1.02	.62
% ERROR	34.28	46.49	85.75	99.45	64.66	11.99	39.19	81.62	50.71	139.16	36.55
#SAMPLE	17	17	12	17	16	17	17	10	17	16	17

PETRO CANADA ST.JOSEPH OIL SHALE PROJECT

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	QU/FE	CA/DO
61.00	10.92	.53	0.00
65.00	5.31	.67	.02
66.00	10.68	.57	.03
68.00	9.24	.69	0.00
69.00	14.06	.72	0.00
71.00	20.36	.67	0.00
72.00	11.98	.73	0.00
74.00	9.93	.76	0.00
75.00	10.86	1.46	0.00
81.00	7.10	1.15	.02
127.00	51.99	1.66	.19
129.00	23.89	1.54	1.66
130.00	11.26	1.24	109.22
132.00	24.15	1.16	6.05
133.00	43.88	1.38	2.47
135.00	36.55	1.32	.77
136.00	34.26	1.44	.08

Table 4 (cont'd)

TABLE 5

Mineralogy Summary and Correlation

	Dover 1	Dover 2	Boudreau 1
illite	moderate 17.8±8	moderate 19±8	high 28±9.6
kaolinite	high 7±35	variable 2.2±2.7	low 1.9±0.9
chlorite	high 1.8±1.1	erratic, low 0.41±0.48	low, erratic 0.27±0.23
analcite	erratic, high 5±3	variable 2.4±2.2	low, erratic 0.72±0.72
pyroxene	erratic 1.4±0.6	consistent 1.2±0.6	low 0.89±0.58
quartz	16±4.7	16±3.2	16±1.9
feldspar	high 30±6.0	high 26±6.2	low, variable 18±7
calcite	consistent 6±4.3	erratic 6.6±5.9	erratic high 9.4±7.7
dolomite	erratic, low 13±10.4	consistent, high 25.6±8.7	high 26.4±13.4
siderite	erratic 0.54±0.32	high, consistent 1.65±1.2	erratic, low 0.73±1.0
pyrite	erratic 3.4±2.4	consistent, high 3.4±1.5	low, 1.7±0.62
ill/kao	very low 1.2±1.2	high 11.7±13.5	moderate 7.3±4.9
qtz/fsp	consistent 1.6±0.7	erratic 1.8±0.6	erratic, high 2.9±1.2
cal/dol	moderate, variable 4.0±7.2	erratic, very low 0.7±0.9	high, variable 20.5±58

DATE: 1

Table 6. MINERALOGY OF DOWNING CREEK OIL SHALE

PROJECT.#: G/S-74
USER: COAL

BULK SHALE

DEPTH	SM/M.L	ILLITE	KAOLIN	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE	
X-FACTOR	7.50	11.50	4.00	1.80	1.00	2.80	.90	1.53	1.15	3.50	
3151.00	3.11	17.60	4.51	.00	22.09	13.00	6.00	26.54	.94	6.22	
3152.00	10.21	17.31	6.32	1.90	14.37	23.11	6.43	18.37	.40	1.57	
3153.00	12.89	15.37	3.88	5.56	13.14	24.64	3.27	19.72	.33	1.21	**Frederick**
3154.00	13.97	15.97	4.72	0.00	10.09	18.46	.00	34.18	0.00	2.61	**Brook**
3155.00	5.76	15.31	1.00	0.00	16.57	30.38	11.20	17.03	0.00	1.08	**Facies**
3156.00	4.30	10.14	1.81	0.00	28.49	21.06	14.81	18.65	0.00	.75	
3157.00	26.17	22.57	2.71	0.00	13.90	19.97	6.59	8.09	0.00	0.00	
3158.00	24.73	23.43	2.64	1.67	16.48	27.55	.00	2.86	.64	0.01	**Dawson**
3159.00	12.77	9.08	3.96	.00	16.82	28.76	12.07	15.76	0.00	.77	**Settlement**
3160.00	14.11	14.24	3.67	1.86	15.57	24.33	8.10	17.87	.24	.00	**Facies**
3161.00	15.09	35.00	3.40	.00	13.42	19.70	5.53	7.51	.34	0.00	
3170.00	2.47	12.78	13.90	.00	22.21	18.95	24.35	1.81	0.00	3.53	
3169.00	2.55	38.23	7.69	0.00	20.36	16.33	13.53	1.32	0.00	0.00	
3168.00	1.47	11.87	14.20	0.00	21.64	15.16	33.34	2.33	0.00	0.01	
3166.00	1.24	21.82	7.00	.00	21.39	24.16	5.79	15.32	0.00	3.28	
3167.00	0.00	23.46	4.11	.00	21.37	21.74	3.70	19.26	0.00	6.36	
3165.00	3.69	41.62	5.30	0.00	22.91	21.16	2.53	2.25	0.00	.56	**Downing**
3164.00	10.48	27.72	13.96	0.00	25.57	16.29	4.79	.53	.65	0.01	**Creek**
3163.00	1.90	34.90	4.25	.00	22.80	19.57	4.87	10.67	0.00	1.04	**Facies**
3162.00	4.98	24.84	7.11	0.00	22.19	15.62	14.58	9.87	0.00	.82	

STATISTICS

MEAN	9.05	21.66	5.85	1.00	19.07	21.00	9.08	12.54	.51	2.13
T.DEV.	7.55	9.59	3.89	1.73	4.78	4.68	8.18	9.32	.25	2.04
ERROR	83.46	44.28	66.46	172.51	25.06	22.31	90.15	74.37	49.18	95.84
SAMPLE	19	20	20	11	20	20	20	20	7	14

MINERALOGY OF DOWNING CREEK OIL SHALE

BULK SHALE

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	QU/FE	CA/DO
3151.00	3.90	1.70	.23
3152.00	2.74	.62	.35
3153.00	3.97	.53	.17
3154.00	3.38	.55	.00
3155.00	8.52	.55	.63
3156.00	5.62	1.35	.79
3157.00	8.31	.70	.81
3158.00	8.89	.60	.00
3159.00	2.29	.58	.77
3160.00	3.88	.64	.45
3161.00	10.28	.68	.74
3170.00	.92	1.17	13.47
3169.00	4.97	1.25	10.27
3168.00	.84	1.43	14.33
3166.00	3.11	.89	.38
3167.00	5.71	.98	.19
3165.00	7.86	1.08	1.13
3164.00	1.99	1.57	9.03
3163.00	8.22	1.16	.46
3162.00	3.49	1.42	1.40

STATISTICS

	IL/KA	QU/FE	CA/DO
MEAN	4.94	.97	2.78
ST.DEV.	2.84	.39	4.74
% ERROR	57.44	39.83	170.11
#SAMPLE	20	20	20

Table 6 (cont'd)

1

DATE: 17/8/82

PROJECT.#: G/S-74
USER: COAL DIV.

TABLE 7. MINERALOGY OF BOYD CREEK SHALES

BULK SHALES

DEPTH	M. LAY	SMECTI	ILLITE	KAOLIN	CHLORI	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRIT
X-FACTOR	7.50	7.50	11.50	4.00	2.60	1.80	1.00	2.80	.90	1.53	1.15	3.50
3179.00	0.00	11.96	28.00	9.28	.58	0.00	29.24	12.53	7.60	.57	.25	0.00
3190.00	0.00	9.63	31.90	5.48	.40	.02	31.50	9.33	10.53	1.22	0.00	0.00
3180.00	12.86	12.16	0.00	4.28	0.00	.44	23.83	23.01	20.53	2.43	.45	0.00
3181.00	8.28	3.68	0.00	1.26	0.00	0.00	38.68	9.16	11.43	22.78	0.00	4.73
3182.00	0.00	1.08	7.05	1.25	0.00	0.00	23.53	5.92	1.72	59.11	.34	0.00
3183.00	0.00	0.00	8.19	8.05	0.00	0.00	28.23	29.92	3.90	20.85	.86	0.00
3191.00	21.84	0.00	0.00	10.75	0.00	0.00	25.40	13.04	23.99	0.00	.42	4.56
3192.00	7.63	0.00	0.00	5.87	.54	0.00	36.23	35.81	8.43	1.98	.10	3.41
3193.00	16.29	0.00	0.00	17.20	.75	0.00	28.06	17.66	2.69	0.00	0.00	17.35

STATISTICS

MEAN	13.38	7.70	18.78	7.05	.57	0.00	29.41	17.38	10.09	15.56	.40	7.51
ST.DEV.	5.90	5.04	13.00	5.02	.14	0.00	5.27	10.21	7.72	21.46	.26	6.59
% ERROR	44.10	65.47	69.19	71.20	25.36	0.00	17.91	58.78	76.47	137.90	64.12	87.66
#SAMPLE	5	5	4	9	4	2	9	9	9	7	6	4

TABLE 7(CONT'D). MINERALOGY OF BOYD CREEK SHALES

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	M./KA	QU/FE	CA/DO
3179.00	0.00	2.33	13.38
3190.00	0.00	9.45	14.72
3180.00	1.60	2.90	14.34
3181.00	3.52	11.82	.85
3182.00	0.00	11.13	.05
3183.00	0.00	2.64	.32
3191.00	1.08	5.45	0.00
3192.00	.69	2.83	7.22
3193.00	.51	4.45	0.00

STATISTICS

MEAN	1.48	5.89	7.27
ST.DEV.	1.21	3.86	6.88
% ERROR	81.93	65.49	94.72
#SAMPLE	5	9	7

DATE: 17/0/02 Table 7(cont'd) MINERALOGY OF BOYD CREEK SHALES

PROJECT.#: G/S-74
USER: COAL DIV.

CLAY <2UM

DEPTH	M. LAY	SMECTI	ILLITE	KAOLIN	CHLORI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	7.50	7.50	11.50	4.00	2.60	1.00	2.80	.90	1.53	1.15	3.50
3179.00	56.16	13.73	0.00	13.70	4.53	.00	8.37	2.84	0.00	.67	0.00
3190.00	74.38	4.00	0.00	9.28	1.79	.00	5.99	1.76	.93	1.85	0.01
3180.00	52.46	11.57	0.00	10.44	1.01	.00	19.10	4.28	0.00	1.14	0.00
3181.00	29.24	10.17	0.00	8.24	4.23	.01	12.37	8.14	23.55	0.00	4.05
3182.00	0.00	7.27	41.25	1.15	0.00	.02	15.41	0.00	34.40	.49	0.00
3183.00	0.00	2.08	14.40	8.45	0.00	.01	47.65	5.42	17.03	4.96	0.01
3191.00	66.64	0.00	0.00	13.46	2.20	.00	13.35	2.53	1.82	0.00	0.00
3192.00	66.14	0.00	0.00	17.72	3.15	.00	10.01	1.49	.72	.77	0.01
3193.00	53.46	0.00	0.00	21.93	6.46	.00	14.15	1.49	1.01	1.21	.28

STATISTICS

MEAN	56.93	8.14	0.00	11.60	3.34	.01	16.27	3.49	11.35	1.59	0.00
T.DEV.	14.62	4.51	0.60	6.01	1.87	.01	12.39	2.34	13.73	1.55	0.01
ERROR	25.69	55.41	0.00	51.85	56.11	74.17	76.18	66.98	120.98	98.00	0.00
SAMPLE	7	6	2	9	7	9	9	8	7	7	2

MINERALOGY OF BOYD CREEK SHALES

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	M./KA	QU/FE	CA/DO
3179.00	0.00	2.33	13.38
3180.00	3.01	1.04	8.43
3181.00	6.59	4.22	.50
3182.00	0.00	3.97	.03
3183.00	0.00	.94	.19
3190.00	0.00	3.38	8.66
3191.00	2.03	1.95	0.00
3192.00	1.30	1.01	4.25
3193.00	.95	1.59	0.00

STATISTICS

MEAN	2.78	2.27	5.06
ST.DEV.	2.27	1.29	5.23
% ERROR	81.93	56.95	103.30
#SAMPLE	5	9	7

MINERALOGY OF BOYD CREEK SHALES

CLAY <2UM

TABLE OF MINERAL RATIOS

DEPTH	M./KA	QU/FE	CA/DO
3179.00	4.10	.00	0.00
3190.00	8.02	.00	1.90
3180.00	5.03	.00	0.00
3181.00	3.55	.00	.35
3182.00	0.00	.00	0.00
3183.00	0.00	.00	.32
3191.00	4.95	.00	1.39
3192.00	3.73	.00	2.06
3193.00	2.44	.00	1.47

STATISTICS

MEAN	4.55	.00	1.25
ST.DEV.	1.77	.00	.75
% ERROR	38.89	66.68	60.30
#SAMPLE	7	9	6

Table 7(cont'd)

```
DATE:  17/8/82          Table 8        MINERALOGY OF LE BLANC CREEK SHALES

PROJECT.#: G/S-74                               BULK SHALES
USER:      COAL DIV.

  DEPTH    M. LAY  SMECTI  KAOLIN  ANALCI  QUARTZ  FELDSP  CALCIT  DOLOMI  SIDERI  PYRITE

X-FACTOR    7.50   11.50    4.50    1.79    1.00    2.80     .90    1.50    1.10    3.50
3174.00     6.43   19.99    7.52     .51   26.43   23.36    0.00   15.50     .25    0.00
3175.00    13.19    0.00   20.69    0.00   26.20    8.48   24.57    1.79    0.00    5.08
3176.00    27.54    0.00   11.93    0.00   17.29   21.30    3.80    3.94     .71   13.48


                                   STATISTICS
   MEAN    15.72    0.00   13.38    0.00   23.31   17.71    0.00    7.08    0.00    0.00
 T.DEV.    10.78    0.00    6.70    0.00    5.21    8.06    0.00    7.37    0.00    0.00
  ERROR    68.57    0.00   50.09    0.00   22.37   45.51    0.00  104.14    0.00    0.00
 SAMPLE        3       1       3       1       3       3       2       3       2       2
```

```
DATE:  17/8/82                         MINERALOGY OF LE BLANC CREEK SHALES

PROJECT.#: G/S-74                               CLAY <2UM
USER:      COAL DIV.

  DEPTH    M. LAY  SMECTI  KAOLIN  CHLORI  ANALCI  QUARTZ  FELDSP  CALCIT  DOLOMI  SIDERI  PYRITE

X-FACTOR    7.50   11.50    4.00    2.60    1.79    1.00    2.80     .90    1.53    1.15    3.50
3176.00    66.07    0.00   17.13    4.02    0.00     .00    8.99    1.34    1.42    0.00    1.02
3175.00    43.08    0.00   46.99    3.10    0.00     .00    2.55    2.21     .66     .77     .64
3174.00    65.70   15.36   10.58    0.00     .40     .00    6.23    0.00     .81     .33     .58


                                   STATISTICS
   MEAN    58.28    0.00   24.90    0.00    0.00     .00    5.92    0.00     .97    0.00     .75
 T.DEV.    13.17    0.00   19.41    0.00    0.00     .00    3.23    0.00     .40    0.00     .24
  ERROR    22.59    0.00   77.95    0.00    0.00   12.32   54.57    0.00   41.51    0.00   32.68
 SAMPLE        3       1       3       2       1       3       3       2       3       2       3
```

MINERALOGY OF LE BLANC CREEK SHALES

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	M./KA	QU/FE	CA/DO
3174.00	.86	1.13	0.00
3175.00	.64	3.09	13.70
3176.00	2.31	.81	.96
	STATISTICS		
MEAN	1.27	1.68	0.00
ST.DEV.	.91	1.23	0.00
% ERROR	71.69	73.50	0.00
#SAMPLE	3	3	2

MINERALOGY OF LE BLANC CREEK SHALES

CLAY <2UM

TABLE OF MINERAL RATIOS

DEPTH	M./KA	CH/KA	CA/DO
3176.00	3.86	.23	.95
3175.00	.92	.07	3.34
3174.00	6.21	0.00	0.00
	STATISTICS		
MEAN	3.66	0.00	0.00
ST.DEV.	2.65	0.00	0.00
% ERROR	72.43	0.00	0.00
#SAMPLE	3	2	2

Table 8(cont'd)

DATE: 17/8/82

Table 9. MINERALOGY OF TAYLOR VILLAGE SHALES

PROJECT.#: G/S-74
USER: COAL DIV.

BULK SHALES

DEPTH	SM/M.L	ILLITE	KAOLIN	CHLORI	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	7.50	11.50	4.00	2.60	1.79	1.00	2.80	.90	1.53	1.15	3.50
3184.00	0.00	17.96	0.00	0.00	1.12	17.69	36.14	.71	26.23	.15	0.00
3185.00	0.00	19.49	0.00	0.00	1.00	7.41	59.05	0.00	12.14	.90	.01
3186.00	0.00	7.49	0.00	.75	1.09	17.13	39.57	0.00	28.67	.57	2.73
3187.00	0.00	10.71	0.00	2.46	2.28	8.46	31.79	1.64	30.56	4.44	7.65
3189.00	9.38	0.00	3.24	0.00	.21	15.60	31.52	0.00	37.61	.44	1.99

STATISTICS

MEAN	0.00	13.91	0.00	0.00	1.14	13.66	39.61	0.00	27.04	1.30	3.10
T.DEV.	0.00	5.75	0.00	0.00	.74	5.39	11.36	0.00	9.35	1.78	3.25
ERROR	0.00	41.30	0.00	0.00	64.80	39.43	28.68	0.00	34.56	136.92	104.86
SAMPLE	1	4	1	2	5	5	5	2	5	5	4

DATE: 17/8/82

MINERALOGY OF TAYLOR VILLAGE SHALES

PROJECT.#: G/S-74
USER: COAL DIV.

CLAY (2UM

DEPTH	M. LAY	ILLITE	KAOLIN	CHLORI	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	7.50	11.50	4.00	2.60	1.79	1.00	2.80	.90	1.53	1.15	3.50
3184.00	0.00	81.26	0.00	0.00	.27	.00	10.69	1.00	5.60	0.00	1.17
3185.00	0.00	59.40	.93	0.00	.62	.01	34.23	2.15	1.64	.38	.66
3186.00	0.00	21.45	3.00	0.00	1.23	.01	54.12	0.00	17.28	2.91	0.00
3187.00	0.00	34.89	.69	0.00	1.40	.01	42.51	2.30	14.77	3.43	0.00
3189.00	58.90	0.00	23.98	.85	0.00	.00	8.46	.79	6.46	.56	0.00

STATISTICS

MEAN	0.00	49.25	7.15	0.00	.88	.01	30.00	1.56	9.15	1.82	0.00
T.DEV.	0.00	26.50	11.27	0.00	.53	.00	19.96	.77	6.59	1.57	0.01
ERROR	0.00	53.80	157.65	0.00	60.12	58.13	66.51	49.64	72.07	86.41	0.00
SAMPLE	1	4	4	1	4	5	5	4	5	4	2

MINERALOGY OF TAYLOR VILLAGE SHALES

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	IL/CH	AN/QU	FE/CA
3134.00	0.00	.06	50.75
3185.00	0.00	.13	0.00
3186.00	9.95	.06	0.00
3187.00	4.35	.27	19.44
3189.00	0.00	.01	0.00
	STATISTICS		
MEAN	0.00	.11	0.00
ST.DEV.	0.00	.10	0.00
% ERROR	0.00	93.25	0.00
#SAMPLE	2	5	2

MINERALOGY OF TAYLOR VILLAGE SHALES

CLAY <2UM

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	FE/CA	FE/DO
3184.00	0.00	10.64	1.91
3185.00	64.18	15.94	20.92
3186.00	7.15	0.00	3.13
3187.00	50.69	18.49	2.08
3189.00	0.00	10.76	1.31
	STATISTICS		
MEAN	40.68	13.96	6.03
ST.DEV.	29.81	3.90	8.36
% ERROR	73.28	27.97	138.57
#SAMPLE	3	4	5

Table 9.(cont'd)

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1 DATE: 16/8/82                        TABLE 10.    MINERALOGY OF ARCO BOUDREAU NO.1

  PROJECT.#: G/S-74                                 BULK SHALES
  USER:      COAL DIV.

    DEPTH    SM/M.L  ILLITE  KAOLON  CHLORI  ANALCI  QUARTZ  FELDSP  CALCIT  DOLOMI  SIDERI  PYRITE

  X-FACTOR     7.50   11.50    4.00    2.60    1.80    1.00    2.80     .90    1.53    1.15    3.50
    76.00      0.00   19.52    3.19     .74    0.00   15.50   48.54    0.00    7.58    0.00    4.94
   168.00     23.00    0.00   15.40     .62     .58   19.23   25.55    0.00   11.46    0.00    4.16
   244.00      0.00   14.08    1.53    1.09    4.76   10.65   27.95     .59   31.65     .77    6.92
   340.00      5.29    0.00    1.06    0.00     .21   14.99   48.75    0.00   27.91     .44    1.35
   354.00      0.00    9.63    0.00    0.00     .21    7.60   53.95    0.00   23.24    5.37    0.00
   369.00     42.23    0.00    1.03     .22    0.00   21.99   18.98    5.01    3.67    6.87    0.00
   457.00     40.04    0.00     .87     .45     .43   17.47   17.32    1.05   20.44    1.93    0.00


                                    STATISTICS
     MEAN     27.64   14.41    3.85     .62    1.24   15.35   34.43    2.22   17.99    3.08    4.34
  ST.DEV.     17.20    4.95    5.72     .33    1.97    4.93   15.48    2.43   10.60    2.88    2.31
  % ERROR     62.25   34.37  148.78   52.47  159.52   32.13   44.95  109.43   58.92   93.68   53.16
  #SAMPLE         4       3       6       5       5       7       7       3       7       5       4
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1
 DATE:  17/8/82                                   TABLE 10(CONT'D). MINERALOGY OF ARCO BOUDREAU #1

 PROJECT.#: G/S-74                                             CLAY(<2 UM)
 USER:      COAL DIV.

    DEPTH    SM/M.L   ILLITE   KAOLIN   CHLORI   ANALCI   QUARTZ   FELDSP   CALCIT   DOLOMI   SIDERI   PYRITE

 X-FACTOR      7.50    11.50     4.00     2.60     1.79     1.00     2.80      .90     1.53     1.15     3.50
    76.00      0.00    40.19     7.53     1.28     0.00      .01    38.26      .32     7.85     0.00     4.56
   168.00     46.09     0.00    35.71     6.65      .08      .00     5.53      .00     2.12     3.81     0.00
   244.00      0.00    68.62     3.27     1.68     2.49      .01    13.67     1.04     7.32     1.91     0.00
   340.00     23.44     0.00     4.00     2.83     0.00      .01    50.55      .37    18.32      .47      .03
   354.00      0.00    13.02     1.87     0.00     0.00      .01    64.90     0.00    14.20     5.99     0.00
   369.00     76.22     0.00     3.87     2.07     0.00      .00    13.42     1.03     0.00     2.98      .40
   412.00     84.55     0.00      .43      .78     0.00      .00     8.14      .10     4.80      .48      .73
   457.00     71.29     0.00      .19      .88     0.00      .00    19.22     1.78     6.32      .31     0.00


                                         STATISTICS
     MEAN     60.32    40.61     7.11     2.31     0.00      .01    26.71      .66     8.70     2.28     1.43
  ST.DEV.     25.11    27.80    11.79     2.04     0.00      .00    21.90      .64     5.62     2.13     2.11
  % ERROR     41.64    68.46   165.85    88.45     0.00    75.10    81.98    97.17    64.60    93.36   147.46
  #SAMPLE         5        3        8        7        2        8        8        7        7        7        4
```

TABLE 10(CONT'D) MINERALOGY OF ARCO BOUDREAU NO.1

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	SM/IL	QU/FE	CA/DO
76.00	0.00	.32	0.00
168.00	0.00	2.11	0.00
244.00	0.00	1.07	.03
340.00	0.00	.86	0.00
354.00	0.00	.39	0.00
369.00	0.00	3.24	2.32
457.00	0.00	2.83	.09

STATISTICS

	SM/IL	QU/FE	CA/DO
MEAN	0.00	1.55	.81
ST.DEV.	0.00	1.18	1.30
% ERROR	0.00	76.40	160.51
#SAMPLE	0	7	3

CLAY(<2 UM)

TABLE OF MINERAL RATIOS

DEPTH	SM/KA	KA/CH	CA/DO
76.00	0.00	5.88	.04
168.00	.69	3.49	.00
244.00	0.00	1.26	.24
340.00	3.13	.92	.03
354.00	0.00	0.00	0.00
367.00	10.49	1.22	0.00
412.00	103.68	.36	.03
457.00	199.50	.14	.48

STATISTICS

	SM/KA	KA/CH	CA/DO
MEAN	63.50	1.90	.14
ST.DEV.	87.34	2.07	.19
% ERROR	137.54	109.07	135.64
#SAMPLE	5	7	6

DATE: 17/8/82 Table 11. MINERALOGY OF BILLS CREEK SHALES

BULK SHALES

PROJECT.#: G/S-74
USER: COAL DIV.

DEPTH	SM/M.L	ILLITE	KAOLIN	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	7.50	11.50	4.00	1.79	1.00	2.80	.90	1.53	1.15	3.50
3178.00	0.00	11.72	3.18	0.00	25.97	23.91	1.52	31.08	.83	1.80
3172.00	0.00	7.38	1.53	.21	22.96	27.09	.00	38.91	.00	1.90
3171.00	10.37	10.85	5.70	.26	10.34	8.24	37.45	0.00	.69	.02

DATE: 17/8/82 MINERALOGY OF BILLS CREEK SHALES

CLAY <2UM

PROJECT.#: G/S-74
USER: COAL DIV.

DEPTH	SMECTI	ILLITE	KAOLIN	CHLORI	ANALCI	QUARTZ	FELDSP	CALCIT	DOLOMI	SIDERI	PYRITE
X-FACTOR	7.50	11.50	4.00	2.60	1.79	1.00	2.80	.90	1.53	1.15	3.50
3178.00	0.00	28.47	15.07	5.69	.58	.01	33.83	1.83	11.33	2.43	.76
3172.00	0.00	19.69	4.60	.88	0.00	.01	44.16	2.59	26.22	1.85	0.00
3171.00	15.69	58.75	10.14	0.00	.09	.01	7.06	8.27	0.00	0.00	0.00

MINERALOGY OF BILLS CREEK SHALES

BULK SHALES

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	QU/FE	CA/DO
3178.00	3.68	1.09	.05
3172.00	4.82	.85	.00
3171.00	3.26	2.22	0.00

MINERALOGY OF BILLS CREEK SHALES

CLAY <2UM

TABLE OF MINERAL RATIOS

DEPTH	IL/KA	KA/CH	CA/DO
3178.00	1.89	2.65	.16
3172.00	4.28	5.22	.10
3171.00	5.80	0.00	0.00

Table 11.(cont'd)

Section 2

Major Element Chemistry of Oil Shale

2a. Major Element Chemistry of Oil Shale

D. Abbott, 1970. Chemical Composition of New Brunswick Rocks, Minerals and Ores. Research and Productivity Council, Minerals and Material Sciences Department, Record 9, Pages 56-57.

TABLE 8 - ARGILLACEOUS ROCKS

	a. SiO_2/Al_2O_3 = 5-4		b. SiO_2/Al_2O_3 = 4-3						
	CaO < 1%	CaO > 1%	CaO < 1%					CaO - 1%-5%	
	1	2	1	2	3	4	5	6	7
Rock Name	Shale	Shale (Unburnt)	Shale	Shale	Shale	Shale	Shale	Shale (Palaeozoic)	Shale
Locality	Queenstown, Queen's Co.	Albert Mines, Alb. Co.	Caraquet, Glouc. Co.	Chipman, Queen's Co.	Chatham, North. Co.	Stonehaven, Glouc. Co.	Gagetown, Queen's Co.	Elbow, North & Rest. Cos.	Chipman, Queen's Co.
Approx. Co-ords	45° 41' N 66° 07' W	45° 42' N 64° 40' W	47° 48' N 64° 57' W	46° 11' N 65° 53' W	47° 02' N 65° 28' W	47° 45' N 65° 22' W	45° 47' N 66° 09' W	47° 30' N 66° 28' W	46° 11' N 65° 53' W
Reference	Barnett & Abbott, 1966 47	Greig, 1943 NB 15	Barnett & Abbott, 1966 41	Barnett & Abbott, 1966 64,65	Barnett & Abbott, 1966 56	Barnett & Abbott, 1966 42	Barnett & Abbott, 1966 23,28	Loudon, 1960	Greig, 1943 NB 8
SiO_2	68.29	53.22	63.92	63.91	62.72	58.37	58.18	63.7	58.48
Al_2O_3	13.73	12.60	16.18	16.70	16.61	18.18	18.53	17.5	18.74
Fe_2O_3	6.29	5.98	6.18	6.30	6.38	7.83	6.16	4.3	6.80
FeO								3.1	
MgO	1.11		1.77	1.52	1.83	2.28	2.02	2.5	
CaO	0.13	2.23	0.38	0.30	0.76	0.55	0.10	1.5	1.19
Na_2O	0.10		1.16	0.21	0.23	0.84	0.09	1.1	
K_2O	2.25		3.00	3.11	3.70	3.25	5.09	3.8	
H_2O+									
H_2O-									
CO_2								1.5	
TiO_2	1.03	0.60	1.09	1.22	1.06	1.03	1.03	0.8	1.13
P_2O_5								0.5	
MnO	0.06		0,06	0.08	0,07	0.08	0.13	tr	
Ig Loss	6.10	15.96	5.20	4.47	4.91	5.54	5.06		6.22

TABLE 8 - ARGILLACEOUS ROCKS

	b. SiO_2/Al_2O_3 = 4-3				c. SiO_2/Al_2O_3 < 3				
	CaO = 1%-5%			CaO > 5%	CaO < 1%				
	8	9	10	11	1	2	3	4	5
Rock Name	Shale	Shale	Shale	Shale (Spent)	Shale	Shale	Shale	Shale	Shale (Carboniferous)
Locality	Taylor Village, West. Co.	Clifton, Glouc. Co.	Irishtown, West. Co.	Albert Mines, Alb. Co.	Flower's Cove, (Grand L.) Sun. Co.	Beersville, Kent Co.	Alma, Alb. Co.	Stonebrook, King's Co.	Alma, Alb. Co.
Approx. Co-ords.	45° 56' N 64° 33' W	47° 44' N 65° 33' W	46° 13' N 64° 48' W	45° 52' N 64° 40' W	46° 02' N 66° 02' W	46° 26' N 65° 04' W	45° 36' N 64° 57' W	45° 47' N 65° 23' W	45° 36' N 64° 57' W
Reference	Barnett & Abbott, 1966 21	Greig, 1943 NB 20-25	Barnett & Abbott, 1966 48	Greig, 1943 NB 31-33	Maxwell, 1965 510	Barnett & Abbott, 1966 39,40	Greig, 1943 NB 11	Barnett, 1967 20	Barnett, 1967 57
SiO_2	55.00	53.04-65.52	51.29	42.11-46.71	63.68	57.47	57.44	56.76	55.97
Al_2O_3	16.76	16.16-22.00	16.25	13.06-14.80	23.80	19.49	20.17	19.59	21.60
Fe_2O_3	7.63	4.87- 9.50	6.80	5.60- 6.53	1.30	5.73	7.81	8.04	7.45
FeO									
MgO	1.18		2.96		0.20	1.37		2.35	1.88
CaO	1.44	1.07- 4.07	4.45	8.07-12.54	0.40	0.70	0.05	0.50	0.35
Na_2O	2.80		5.32		1.43	0.17		1.77	0.27
K_2O	3.16		3.13			3.85		3.68	4.10
H_2O+					8.77				
H_2O-									
CO_2									
✓ TiO_2	0.85	0.84- 0.95	0.74	0.22- 0.58		1.00	0.85	1.00	0.87
✓ P_2O_5									
✓ MnO	0.15		0.16			0,06		0.06	0.06
Ig Loss	10,06	4.82- 7.71	8.76	11.38-16.31		8.36	8.02		
S									

2b. Major Element Chemistry of Oil Shale

D. Abbott and D.E. Barnett, 1968. Composition of Oil Shale and Coal Ashes, New Brunswick. Research and Productivity Council, Minerals and Material Sciences Department, Research Note 14, Page 8.

TABLE 1

MAJOR AND MINOR ELEMENTS (WT. %)

	Oil Shale	Coal	Peat
SiO_2	42.34 - 65.42	16.01 - 38.80	29.80 - 46.49
TiO_2	0.72 - 1.28	0.35 - 1.59	0.57 - 0.61
Al_2O_3	0.20 - 19.80	5.48 - 15.49	11.49 - 11.97
Fe_2O_3	5.27 - 8.89	22.99 - 70.35	3.39 - 8.77
MnO	0.0 - 0.23	0.0 - 0.14	0.12 - 0.24
MgO	1.62 - 6.88	0.10 - 0.75	18.68 - 25.61
CaO	1.79 - 19.77	0.82 - 4.81	9.29 - 11.19
Na_2O	0.67 - 4.90	0.17 - 0.24	1.62 - 2.12
K_2O	0.04 - 4.39	0.42 - 1.32	0.76 - 1.35
P_2O_5	0.39 - 2.58	1.92 - 4.14	3.76 - 4.03
S	0.05 - 0.56	0.52 - 1.80	4.20 - 5.67
No. of Analyses	14	9	2

2c. Major Element Chemistry of Oil Shale

R. Boorman, P. Salib, I. Wilkomirsk, R. Salter and R. Gilders, 1982. Design Concepts and Preliminary Economics for Coal/Oil Shale Combustion Retort Systems. Department of Natural Resources, Mineral Resources Division, Open File Report 82-28, Appendix A-5.

TABLE A - 3

ANALYSES OF FRESH OIL SHALE, COAL ASH, AND COMBUSTION CALCINES

Composition	Fresh Oil Shale (-8 to +50 mesh) OSC -17a to OSC -18c	Coal Ash (-¼" to + 20 mesh) OSC -17a to OSC -18c		Calcines from OSC -16c	
		Sample a	Sample b	Bed	Fines
SiO_2	40.78	40.61	38.79	48.20	39.29
Al_2O_3	12.87	19.01	17.12	17.05	14.92
Fe_2O_3	5.20	31.45	34.85	6.43	17.16
MgO	3.58	1.84	0.58	4.76	3.30
CaO	10.75	3.50	3.32	12.60	9.72
Na_2O	1.28	0.87	0.44	1.20	1.50
K_2O	1.61	2.78	2.36	2.02	1.41
P_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01
MnO	0.12	0.16	0.17	0.14	0.12
TiO_2	0.37	0.33	0.40	0.40	<0.2
Ignition Loss	21.62	-	-	5.29	14.54
Total	98.26	100.55	98.03	98.09	101.96

2d. Major Element Chemistry of Oil Shale

J. Leveille, 1977. Inventory of Shale Deposits of New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Branch, Open File Report 77-9, Pages 4-7, 9, 15, 21-23, 29.

ALBERT MINES SHALE

"The shales at Albert Mines vary from thinly bedded brown "paper" shales to thicker bedded grey to black carbonaceous shales. A few thin, sandy, shale beds occur within the series, as well as a considerable thickness of gritty grey to brown shale. All the shales are rather hard and brittle and do not slacken on exposure to a soft plastic clay as those in the Minto area. Small calcite stringers are common in fractures in the shale." (Greig, 1943).

Ries and Keele (1911) reported analyses on shale samples from the Frederick Brook near the Albert Mines.

"The sample worked up with 21.2% of water to a somewhat gritty, though plastic mass of which the air shrinkage was 6.2% and average tensile strength 137 pounds per square inch."

"In burning it behaved as follows:"

Cone	Fire Shrinkage%	Absorption%	Colour	Hardness
010	0.3	13.00	Red	
05	0.6	14.55	Red	
03	1	13.37	Red	Steel Hard
1	5.3	7.32	Red brown	
3	Fused			

"It would make either common or pressed brick, but must be fired slowly, on account of the carbon it contains".

Keele (1914) adds that this shale would probably work well for the manufacture of fireproofing.

Greig (1943) describes the analyses performed by Mead on two samples from the Albert Mines.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Fixed Meitter	Total
Shale	49.58	18.84	7.30	9.91	5.68	8.69	100.00
Spent Shale*	54.29	20.63	8.00	10.85	6.23	8.69	100.00

He also reports analyses done on four samples he collected. For the location of these samples, see Map I Albert Mines Region.

*Spent Shale: burned shale

Sample	Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	L.O.I.	Tot
N.B.15	Channel sample of unburned Albert Shale	53.22	12.60	5.98	2.23	0.60	15.96	90.
N.B.31	D.H. 50, represents burnt shale from a 97 foot hole	42.16	14.80	5.86	12.54	0.22	16.31	91.
N.B.32	D.H. 52, represents burnt shale from a 500 foot hole	42.11	14.31	5.66	8.51	0.46	14.53	85.
N.B.33	D.H. 56, represents burnt shale from 981.5 feet of a 1000 foot hole	46.71	13.06	6.53	8.07	0.58	11.32	86.

Barnett and Abbott (1966) report the general mineral composition of brown shales from a 3 foot section on the Frederick Brook, 50 feet on the northeast road and from a 15 foot section on the Frederick Brook in the northeast adit. They contain minor illite; trace chlorite; moderate quartz, trace feldspar; calcite and carbonaceous material.

Wilson (1967) analyzed a grey, carbonaceous shale in a 10 foot section in Frederick Brook, northeast of adit.

The firing tests results are:

Sample #	Unfired Bulk Specific Gravity	Firing T. (°F)	Observations	Fired Bulk Specific Gravity
43-A	1.91	1900	no bloating to slight bloating	1.50
		1950	no bloating to slight bloating	1.21
		2000	no bloating to slight bloating	1.38
43-B	1.71		moderate sticking precalcined at 1300°F for 5 mm.	
		1900	no bloating to slight	1.53

Sample #	Unfired Bulk Specific Gravity	Firing T. (°F)	Observations	Fired Bulk Specific Gravity
			bloating	
		1950	no bloating to slight bloating	1.28
		2000	no bloating to slight bloating	1.43
			severe sticking	

It bloated poorly because of high carbon content, even when precalcined at 1300°F.

Ries, H. and Keele, J.: The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick; G.S.C. Memoir 16-E, 1911.

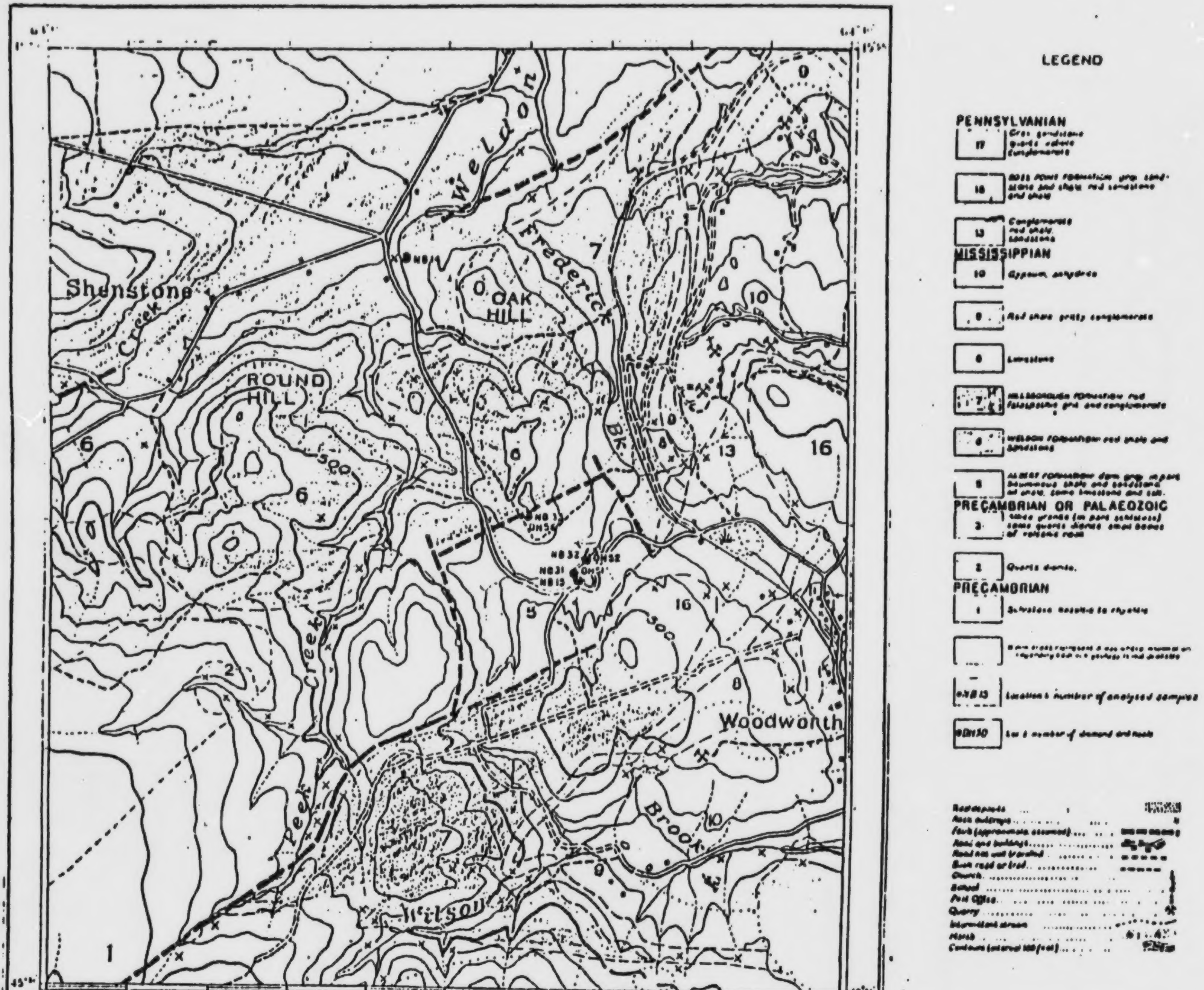
Keele, J.: The Clay and Shale Deposits of New Brunswick; G.S.C. Memoir 44, 1914.

Greig, E.W.: Report on Clay and Shale Deposits of New Brunswick; Aluminum Laboratories Ltd., Mining Engineering and Exploration Department, Montreal, 1943.

Barnett, D.E. and Abbott, D.: The Evaluations of Possible Ceramic Raw Materials from New Brunswick; Research and Productivity Council, Research Note 6, 1966.

Wilson, H.S.: Assessment of Shales and Slates from New Brunswick for Production of Lightweight Aggregate; Mines Branch Investigation Report 67-6, Ottawa, 1967.

Joanne Leveille
March, 1977


Shenstone
Creek
ROUND HILL
OAK HILL
Weldon
Frederick
Bk
Woodworth
Brook
Wilson
Peck
Creek
500
300
NB31
NB32
NB13
DH32
DH34
1
2
5
6
7
8
10
13
16
LEGEND
PENNSYLVANIAN
17 Grey sandstone quartz cobble conglomerate
16 Boss Point formation grey sandstone and shale red sandstone and shale
13 Conglomerate red shale, sandstone
MISSISSIPPIAN
10 Gypsum, anhydrite
8 Red shale gritty conglomerate
8 Limestone
7 Hillsborough formation red feldspathic grit and conglomerate
6 Weldon formation red shale and sandstone
5 Albert formation dark grey in part bituminous shale and sandstone oil shale, some limestone and salt.
PRECAMBRIAN OR PALAEOZOIC
3 Albite granite (in part schistose) some quartz diorite small bodies of volcanic rock
2 Quartz diorite.
PRECAMBRIAN
1 Schistose basaltic to rhyolitic
NB13 Location & number of analysed samples
DH30 Loc & number of diamond drill holes
Rock outcrops
Fault (approximate, assumed)
Road and buildings
Road not well travelled
Bush road or trail
Church
School
Post Office
Quarry
Intermittent stream
Marsh
Contours (interval 100 feet)

ROSEVALE AREA SHALE

Lat. 45°51'N Long. 64°51'19"W

"Rosevale, which lies about six miles west of the Albert Mines area, in Albert County, is on the northeast end of a belt of Albert shales. The belt, striking N60°E varies between one-quarter and one-third of a mile wide and is seven miles long. The Albert shales in the Rosevale area are similar to those at Albert Mines. They are grey to brown, smooth to gritty and sandy, carbonaceous shales."

"N.B. 13 is a channel sample of the shale taken across a five foot thickness in a drift on the west side of Turtle Creek, near Rosevale schoolhouse. N.B. 29* and N.B. 30* are spent shales after oil extraction from the drill cores of holes bored during the summer of 1942 by the Canadian Geological Survey. The analyses of these shales gave the following results."

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	L.O.I.	Total	
N.B.13	41.09	12.59	4.67	7.27	0.48	24.26	90.36	
N.B.29	47.53	13.23	6.30	9.21	0.62	11.42	88.31	Spent Shales
N.B.30	49.91	16.15	5.75	6.38	0.29	12.62	91.10	

Greig, E.W.: Report on Clay and Shale Deposits of New Brunswick; Aluminum Laboratories Limited, Mining Engineering and Exploration Department, Montreal, 1943.

*N.B.29: 45°51'25"N, 64°50'05"W (D.H. 23)
*N.B.30: 45°51'45"N, 64°49'W (D.H. 28)

Joanne Leveille
March, 1977

21 H 15 10

BOUDREAU SHALE

Lat. 45°55'05"N Long. 64°36'30"W

"A short distance northwest of Boudreau village, which is about two miles due south of Belliveau village, shales of the Albert Formation outcrop along the banks of Petitcodiac River. They are dark brown and thinly bedded." (Greig, 1943).

The following results are from analyses performed on a six foot channel sample, N.B. 17, taken near the top of the formation:

SiO_2	Al_2O_3	Fe_2O	CaO	TiO_2	L.O.I.	Total
43.21	9.72	5.13	13.07	0.53	16.48	88.14

From the same occurrence, Barnett and Abbott (1966) described the mineral composition of a brown shale.

It contained minor illite, trace chlorite, moderate quartz and feldspar and calcite. One sample was albertite-rich.

Wilson (1967) tested a shale apparently from the same occurrence on the east side of the Petitcodiac River, two miles south of Belliveau.

Here are the firing tests results:

Sample #	Unfired Bulk Specific Gravity	Firing T. (°F)	Observations	Fired Bulk Specific Gravity
49	2.66	1950	no bloating	2.08
		2000	no bloating	1.91
		2050	no bloating, slight sticking	1.81
		2100	no bloating to moderate bloating, severe sticking	1.10

It bloated too non-uniformly and contained some calcareous pieces.

21 I 27

IRISHTOWN SHALE

Lat. 46°13'N Long. 64°48'W

"Irishtown is located about six miles north of Moncton. Dark grey and brown rusty slates belonging to the Albert Formation outcrop on a northeast trending ridge, two and one-quarter miles north of Irishtown. The slates strike approximately N45°E with dips to the southeast varying between 20 to 40°. They are exposed in a small quarry and on the surface for about 500' across their strike, along the west side of the road, and again in a quarry to the southeast of the above occurrence. They are thin bedded, hard and do not crumple easily on weathering and are better classed as slates than shales." (Greig, 1943).

"A channel sample, N.B. 10 representing a six-foot thickness of the slate was taken two and one-quarter miles north of Irishtown. The following is the analysis of this slate:"

SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	L.O.I.	Total
52.84	16.24	6.11	4.63	0.83	9.15	89.90

Barnett and Abbott (1966) report the sampling of a brown shale in a four and one-half foot section in the quarry two and one-half miles north of the town on Route 31.

It is composed of trace illite and trace interstratified illite/montmorillonite, abundant quartz (57.9%) and feldspar, of some anatase and calcite.

Its chemical analyses gave the following results:

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	NaO_2	K_2O	TiO_2	Ig. Loss	Total
51.29	16.25	6.80	0.16	2.96	4.45	5.32	3.13	0.74	8.76	99.86

They reported the firing tests done by Mercier (1965):

		Fired Characteristics				
Unfired Characteristics	P.C.E.	Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardnes
Brown, very calcareous shale, poor workability, very low plasticity, water of plasticity 16.1%, safe drying, drying shrinkage 2.5%	Cone 1 approx. 2077°F 1136°C	04	+1.3	17.7	Pale Salmon	Soft
		02	0.0	9.6	Brown, Covered With Buff Specks	Fairly Hard

This shale is generally unsatisfactory as a ceramic raw material.

From the same occurrence, Wilson (1967) report the sampling of a black sale in a five foot section in the quarry.

Here are the firing tests results performed on this shale:

Sample #	Unfired Bulk Specific Gravity	Firing T. (°F)	Observations	Fired Bulk Specific Gravity
48	2.68	1900	no bloating	2.02
		1950	no bloating to slight bloating	1.84
		2000	no bloating to good bloating, severe sticking	1.15

The shale bloated too non-uniformly to be used for lightweight aggregate.

Greig, E.W.: Report on Clay and Shale Deposits of New Brunswick; Aluminum Laboratories Limited, Mining Engineering and Exploration Department, Montreal, 1943.

Mercier, H.: Evaluation of Clay and Shale Samples from New Brunswick; Department of Mines and Technical Surveys, MPT 65-40, 1965.

Barnett, D.E. and Abbott, D.: The Evaluation of Possible Ceramic Materials from New Brunswick; N.B. Research and Productivity Council, Research Note 6, 1966.

Wilson, H.S.: Assessment of Shales and Slates from New Brunswick for Production of Lightweight Aggregate; Mines Branch Investigation Report 67-6, 1967.

Joanne Leveille
March, 1977

TAYLOR VILLAGE SHALE

Lat. 45°56'N Long. 64°33'W

Barnett and Abbott (1966) describes a sample of brown shale obtained in a 10 foot section on the west bank of the Memramcook River at Taylor Village.

It contains a trace of illite, moderate quartz (43.9%) and feldspar, some siderite and dolomite.

The following are the results of the chemical analysis:

SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	NaO_2	K_2O	TiO_2	Ig. Loss	Total
55.00	16.76	7.63	0.15	1.18	1.44	2.80	3.16	0.85	10.06	99.03

Mercier (1965) reported that this non-calcareous hard shale had no plasticity and was not suitable for clay products.

Barnett, D.E. and Abbott, D.: The Evaluation of Possible Ceramic Materials from New Brunswick; N.B. Research and Productivity Council, Research Note 6, 1966.

Joanne Leveille
March, 1977

2e. Major Element Chemistry of Oil Shale

J. Synnott and R. Salter, 1983. Modification of Existing Testing Facilities, Optimization of Hydroretorting Conditions and Assessment of Canadian Oil Shales as Source of Synthetic Fuels. The Research and Productivity Council, Mineral Development and Processing, Report Number MDP/83/12, Page 27.

TABLE 4

MAJOR ELEMENT COMPOSITIONS OF RAW SHALES

Sample	SiO_2 (wt %)	Al_2O_3 (wt %)	Fe_2O_3 (wt %)	CaO (wt %)	MgO (wt %)	Na_2O (wt %)	K_2O (wt %)
NB-1	33.88	8.83	4.33	12.40	4.31	1.91	2.04
NB-2a	43.48	17.33	5.13	5.06	1.95	2.02	2.08
NB-2b	46.91	23.23	7.32	2.56	2.36	1.71	3.08
NB-3	48.72	9.40	4.60	6.15	2.16	0.74	0.60
NB-4	38.14	7.27	4.16	12.20	1.31	1.43	1.37
NB-5	38.27	18.85	4.45	7.37	1.63	1.35	1.56
NB-6	25.83	12.54	3.24	23.15	1.18	3.16	1.66
NB-7	16.95	13.47	2.75	14.54	11.01	1.00	0.55
NB-8	22.08	8.25	7.63	16.48	10.14	1.39	0.82
NB-9	41.05	15.28	6.69	4.85	1.82	1.57	2.06
NB-10	40.11	12.90	7.78	9.63	5.20	3.09	1.83
NB-11	39.28	18.19	5.93	3.97	1.69	4.93	1.56
NB-12	39.72	21.24	5.92	4.93	2.43	4.43	2.24
NB-13	40.36	15.90	8.02	6.80	3.61	4.13	2.11
NB-14	39.40	14.53	6.32	10.90	4.77	3.88	2.04
NB-15	43.71	21.17	6.29	7.34	2.64	5.16	3.18
NB-16	27.93	15.54	4.67	5.82	2.51	3.25	1.60

Section 3

Trace Element Chemistry of Oil Shale

3a. Trace Element Chemistry of Oil Shale

D. Abbott, 1970. Chemical Composition of New Brunswick Rocks, Minerals and Ores. Research and Productivity Council, Minerals and Material Sciences Department, Record 9, Page 58.

TABLE 8 - ARGILLACEOUS ROCKS

a. $SiO_2/Al_2O_3 < 3$

	CaO < 1%	CaO = 1%-5%					Trace elements	
	6	7	8	9	10	11	1	
Rock Name	Shale	Shale	Shale	Shale (Carboniferous)	Shale	Oil Shale	Bituminous Shale	
Locality	Cornhill, King's Co.	Cornhill, King's Co.	Alma, Alb. Co.	Cornhill, King's Co.	Clifton, Glouc. Co.	Chipman, Queen's Co.	Albert Mines, Alb. Co.	
Approx. Co-ords.	45° 55' N 65° 21' W	45° 55' N 65° 21' W	45° 38' N 64° 57' W	45° 55' N 65° 21' W	47° 44' N 65° 23' W	46° 11' N 65° 53' W	45° 52' N 64° 40' W	
Reference	Barnett & Abbott, 1966 37,38	Greig, 1943 NB 26	Barnett & Abbott, 1966 57	Barnett, 1967 37	Barnett & Abbott, 1966 52,54	Abbott & Barnett, 1968	Abbott & Barnett, 1968 14 anal.	
SiO_2	55.03	53.90	49.48	55.84	54.30	42.34-65.42	Sb < 200	Pb 50-200
Al_2O_3	19.40	20.24	20.52	19.85	19.34	0.20-19.80	As < 500	Mn
Fe_2O_3	9.95	8.48	6.37	8.28	7.88	5.27- 8.89	Ba 100-500	Mo 50
FeO							Be	Nb
MgO	2.77		1.53	2.82	1.86	1.62- 6.88	Bi < 10	Ni 30- 50
CaO	0.08	0.59	0.38	1.24	1.73	1.79-19.77	B < 50	Ag .05-0.2
Na_2O	1.42		0.25	1.50	0.29	0.07- 4.00	Cd < 50	Sr 500-2000
K_2O	4.38		3.86	4.16	3.22	0.04- 4.30	Cr < 50-200	Sn 50
H_2O+							Co < 50	Ti
H_2O-							Cb 50	V 200
CO_2							Cu < 50-200	W 500
TiO_2	1.00	0.81	0.87	0.94	0.94	0.72- 1.28	Ga 10	Y 50-300
P_2O_5						0.30- 2.58	Ge < 10	Zr 100-200
MnO	0.15		0.04	0.08	0.12	0.0 - 0.23		
Ig Loss	5.01	0.31	15.41		7.76			
S						0.05- 0.50		

3b. Trace Element Chemistry of Oil Shale

D. Abbott and D.E. Barnett, 1968. Composition of Oil Shale and Coal Ashes, New Brunswick. Research and Productivity Council, Minerals and Material Sciences Department, Research Note 14, Page 9.

TABLE 2

TRACE ELEMENTS (WT. %)

	Shale	Albertite	Coal	Peat
% ash	18.2-33.6	< 1	9.2-27.3	0.5 0.8
Sb	< 0.02	< 0.02	< 0.02	< 0.02
As	< 0.05	0.1	< 0.05	< 0.05
Ba	0.05-0.1	0.1	< 0.03-0.05	0.02-0.07
Be			0.001-0.01	
Bi	< 0.001	< 0.001	< 0.001	< 0.001
B	< 0.005		< 0.002	0.01-0.02
Cd	< 0.005	< 0.005	< 0.005	0.005-0.01
Cr	< 0.005-0.02	0.02	0.01-0.05	0.01
Co	< 0.005	1.0	< 0.01	< 0.003
Cb	< 0.005	< 0.005	< 0.005	< 0.005
Cu	< 0.005-0.02	0.05	0.01-0.02	0.02-0.03
Ga	0.001		0.001	0.0005-0.001
Ge	< 0.001	0.01	0.001-0.02	0.001
Pb	0.005-0.02	0.3	0.005	0.03-0.08
Li				
Mo	< 0.005	0.5-1.0	0.005-0.01	0.003-0.008
Ni	0.003-0.005	0.5-5.0	0.005-0.01	0.005-0.05
Re				
Rb				
Ag[*]	0.05-0.2	0.1	0.05-0.1	0.1-0.8
Sr	0.05-0.2		0.05	0.1
Ta	< 0.1	< 0.1		< 0.1
Sn	< 0.005	< 0.005	< 0.005	< 0.005
W	< 0.01	< 0.01	< 0.01	< 0.01
V	0.02	0.1-0.2	0.005-0.01	< 0.01-0.5
Y	0.005-0.03	0.005	< 0.01	0.003-0.005
Zr	0.01-0.02	0.01	0.01-0.02	0.005-0.01
No. of samples	14	1	9	4

[*] oz/ton

3c. Trace Element Chemistry of Oil Shale

R.K. Pickerill and D. Carter, 1980. Sedimentary Facies and Depositional History of the Albert Formation. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 80-2, Pages 118-120, 126, 130.

TABLE IA

Frederick Brook Stream Section

Sample No.	7	8	10	11	12
	ppm	ppm	ppm	ppm	ppm
strontium	1,760	2,060	440	414	1,120
fluoride	397	481	1,131	2,200	407
boron	0.10	0.098	0.10	0.40	0.099
chromium	32	24	61	69	35
lithium	57	68	158	58	55
vanadium	30	67	33	27	27
rubidium	10	40	82	81	15
magnesium	90,000	90,000	26,000	1,800	59,000
aluminum	28,000	20,000	76,000	83,000	19,000
calcium	171,000	151,000	31,000	190,000	18,000
beryllium	2	8	5	4	7
copper	20	13	59	60	17
lead	44	50	52	62	64
zinc	59	41	140	130	44
silver	3	2	3	3	N.D.
nickel	15	14	57	44	20
molybdenum	20	9	26	30	32
uranium	7.8	2.9	10.9	4.5	7.8
gold	N.D.	N.D.	0.10	0.40	N.D.
% phosphate	0.030	N.D.	0.13	0.090	0.060
gallium	N.D.	N.D.	N.D.	N.D.	N.D.
barium	110	100	140	70	80

TABLE 1B

Frederick Brook Stream Section

Sample No.	13	14	15	16	17
	ppm	ppm	ppm	ppm	ppm
strontium	1,010	1,760	1,450	1,020	970
fluoride	402	445	690	1,360	440
boron	0.10	0.15	N.D.	0.15	0.10
chromium	33	33	25	60	65
lithium	50	53	52	97	45
vanadium	23	15	11	25	27
rubidium	10	N.D.	40	114	30
magnesium	96,000	10,000	16,000	25,000	21,000
aluminum	20,000	14,000	51,000	75,000	42,000
calcium	179,000	175,000	180,000	77,000	37,000
beryllium	4	4	5	5	7
copper	17	23	18	90	48
lead	66	36	38	46	48
zinc	56	53	39	110	120
silver	7	2	3	2	5
nickel	23	13	13	59	42
molybdenum	27	16	31	29	45
uranium	11.4	13.4	9.9	10.9	5.0
gold	N.D.	-	N.D.	N.D.	N.D.
% phosphate	0.060	0.060	0.060	1.11	0.060
gallium	N.D.	N.D.	N.D.	N.D.	N.D.
barium	90	100	80	90	60

TABLE 1C

Frederick Brook Stream Section

Sample No.	18	20	24	25
	ppm	ppm	ppm	ppm
strontium	501	220	220	255
fluoride	440	-	220	400
boron	0.55	-	0.10	0.14
chromium	40	41	16	22
lithium	37	65	70	68
vanadium	19	25	12	15
rubidium	10	34	23	41
magnesium	10,000	12,000	7,000	8,000
aluminum	13,000	46,000	23,000	21,000
calcium	38,000	179,000	294,000	280,000
beryllium	6	4	4	4
copper	63	32	13	13
lead	50	50	70	76
zinc	110	100	71	100
silver	4	N.D.	N.D.	2
nickel	42	49	27	30
molybdenum	27	9	15	18
uranium	5.5	3.3	9.1	4.8
gold	-	N.D.	N.D.	N.D.
% phosphate	0.27	-	0.030	0.060
gallium	N.D.	N.D.	N.D.	N.D.
barium	50	110	190	160

TABLE VII

Rosevale

Sample No.	50	51
	ppm	ppm
strontium	660	264
fluoride	561	519
boron	0.55	0.54
chromium	67	75
lithium	46	73
vanadium	160	160
rubidium	60	75
magnesium	38,200	600
aluminum	68,000	80,000
calcium	64,000	3,300
beryllium	2	6
copper	90	106
lead	66	40
zinc	54	90
silver	N.D.	N.D.
nickel	58	63
molybdenum	83	18
uranium	6.6	6.8
gold	N.D.	N.D.
% phosphate	0.030	0.070
gallium	N.D.	N.D.
barium	110	120

TABLE XI

✓

Urney

Sample No.	95	96
	ppm	ppm
strontium	950	-
fluoride	519	-
boron	0.58	-
chromium	94	-
lithium	74	-
vanadium	160	-
rubidium	74	-
magnesium	41,800	-
aluminum	58,000	-
calcium	80,000	-
beryllium	8	9
copper	121	-
lead	70	-
zinc	55	-
silver	N.D.	-
nickel	45	-
molybdenum	18	-
uranium	5.4	8.2
gold	N.D.	-
% phosphate	0.030	-
gallium	N.D.	N.D.
barium	100	100

Section 4

Chemistry of Oil Shale Ash (Spent Shale)

4a. Chemistry of Oil Shale Ash (Spent Shale)

D. Abbott, 1970. Chemical Composition of New Brunswick Rocks, Minerals and Ores. Research and Productivity Council, Minerals and Material Sciences Department, Record 9, Page 57.

TABLE 8 - ARGILLACEOUS ROCKS

b. SiO_2/Al_2O_3 = 4-3

c. SiO_2/Al_2O_3 < 3

	CaO = 1%-5%			CaO > 5%	CaO < 1%				
	8	9	10	11	1	2	3	4	5
Rock Name	Shale	Shale	Shale	Shale (Spent)	Shale	Shale	Shale	Shale	Shale (Carboniferous)
Locality	Taylor Village, West. Co.	Clifton, Glouc. Co.	Irishtown, West. Co.	Albert Mines, Alb. Co.	Flower's Cove, (Grand L.) Sun. Co.	Beersville, Kent Co.	Alma, Alb. Co.	Stonebrook, King's Co.	Alma, Alb. Co.
Approx. Co-ords.	45° 56' N 64° 33' W	47° 44' N 65° 33' W	46° 13' N 64° 48' W	45° 52' N 64° 40' W	46° 02' N 66° 02' W	46° 26' N 65° 04' W	45° 36' N 64° 57' W	45° 47' N 65° 23' W	45° 36' N 64° 57' W
Reference	Barnett & Abbott, 1966 21	Greig, 1943 NB 20-25	Barnett & Abbott, 1966 48	Greig, 1943 NB 31-33	Maxwell, 1965 510	Barnett & Abbott, 1966 39,40	Greig, 1943 NB 11	Barnett, 1967 20	Barnett, 1967 57
SiO_2	55.00	53.04-65.52	51.29	42.11-46.71	63.68	57.47	57.44	56.76	55.97
Al_2O_3	16.76	16.10-22.00	16.25	13.06-14.80	23.80	19.49	20.17	19.59	21.80
Fe_2O_3	7.63	4.87- 9.50	6.80	5.60- 6.53	1.20	5.73	7.81	8.04	7.45
FeO									
MgO	1.18		2.96		0.20	1.37		2.35	1.88
CaO	1.44	1.07- 4.07	4.45	8.07-12.54	0.40	0.70	0.05	0.59	0.35
Na_2O	2.80		5.32		1.43	0.17		1.77	0.27
K_2O	3.16		3.13			3.85		3.68	4.10
H_2O+					8.77				
H_2O-									
CO_2									
✓ TiO_2	0.85	0.84- 0.95	0.74	0.22- 0.58		1.00	0.86	1.00	0.87
✓ P_2O_5									
✓ MnO	0.15		0.16			0.06		0.06	0.06
Ig Loss	10.06	4.82- 7.71	6.76	11.32-16.31		8.36	8.02		
S									

4b. Chemistry of Oil Shale Ash (Spent Shale)

J. Leveille, 1977. Inventory of Shale Deposits of New Brunswick. Department of Natural Resources, Mineral Resources Branch, Open File Report 77-9, Pages 4, 5, 9.

ALBERT MINES SHALE

"The shales at Albert Mines vary from thinly bedded brown "paper" shales to thicker bedded grey to black carbonaceous shales. A few thin, sandy, shale beds occur within the series, as well as a considerable thickness of gritty grey to brown shale. All the shales are rather hard and brittle and do not slacken on exposure to a soft plastic clay as those in the Minto area. Small calcite stringers are common in fractures in the shale." (Greig, 1943).

Ries and Keele (1911) reported analyses on shale samples from the Frederick Brook near the Albert Mines.

"The sample worked up with 21.2% of water to a somewhat gritty, though plastic mass of which the air shrinkage was 6.2% and average tensile strength 137 pounds per square inch."

"In burning it behaved as follows:"

Cone	Fire Shrinkage%	Absorption%	Colour	Hardness
010	0.3	13.00	Red	
05	0.6	14.55	Red	
03	1	13.37	Red	Steel Hard
1	5.3	7.32	Red brown	
3	Fused			

"It would make either common or pressed brick, but must be fired slowly, on account of the carbon it contains".

Keele (1914) adds that this shale would probably work well for the manufacture of fireproofing.

Greig (1943) describes the analyses performed by Mead on two samples from the Albert Mines.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Fixed Meitter	Total
Shale	49.58	18.84	7.30	9.91	5.68	8.69	100.00
Spent Shale*	54.29	20.63	8.00	10.85	6.23	8.69	100.00

He also reports analyses done on four samples he collected. For the location of these samples, see Map I Albert Mines Region.

*Spent Shale: burned shale

Sample	Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	L.O.I.	Total
N.B.15	Channel sample of unburned Albert Shale	53.22	12.60	5.98	2.23	0.60	15.96	90.59
N.B.31	D.H. 50, represents burnt shale from a 97 foot hole	42.16	14.80	5.86	12.54	0.22	16.31	91.89
N.B.32	D.H. 52, represents burnt shale from a 500 foot hole	42.11	14.31	5.66	8.51	0.46	14.53	85.58
N.B.33	D.H. 56, represents burnt shale from 981.5 feet of a 1000 foot hole	46.71	13.06	6.53	8.07	0.58	11.32	86.27

Barnett and Abbott (1966) report the general mineral composition of brown shales from a 3 foot section on the Frederick Brook, 50 feet on the northeast road and from a 15 foot section on the Frederick Brook in the northeast adit. They contain minor illite; trace chlorite; moderate quartz, trace feldspar; calcite and carbonaceous material.

Wilson (1967) analyzed a grey, carbonaceous shale in a 10 foot section in Frederick Brook, northeast of adit.

The firing tests results are:

Sample #	Unfired Bulk Specific Gravity	Firing T. (°F)	Observations	Fired Bulk Specific Gravity
43-A	1.91	1900	no bloating to slight bloating	1.50
		1950	no bloating to slight bloating	1.21
		2000	no bloating to slight bloating	1.38
43-B	1.71		moderate sticking precalcined at 1300°F for 5 mm.	
		1900	no bloating to slight	1.53

ROSEVALE AREA SHALE

Lat. 45°51'N Long. 64°51'19"W

"Rosevale, which lies about six miles west of the Albert Mines area, in Albert County, is on the northeast end of a belt of Albert shales. The belt, striking N60°E varies between one-quarter and one-third of a mile wide and is seven miles long. The Albert shales in the Rosevale area are similar to those at Albert Mines. They are grey to brown, smooth to gritty and sandy, carbonaceous shales."

"N.B. 13 is a channel sample of the shale taken across a five foot thickness in a drift on the west side of Turtle Creek, near Rosevale schoolhouse. N.B. 29* and N.B. 30* are spent shales after oil extraction from the drill cores of holes bored during the summer of 1942 by the Canadian Geological Survey. The analyses of these shales gave the following results."

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	L.O.I.	Total	
N.B.13	41.09	12.59	4.67	7.27	0.48	24.26	90.36	
N.B.29	47.53	13.23	6.30	9.21	0.62	11.42	88.31	Spent
N.B.30	49.91	16.15	5.75	6.38	0.29	12.62	91.10	Shales

Greig, E.W.: Report on Clay and Shale Deposits of New Brunswick; Aluminum Laboratories Limited, Mining Engineering and Exploration Department, Montreal, 1943.

*N.B.29: 45°51'25"N, 64°50'05"W (D.H. 23)
*N.B.30: 45°51'45"N, 64°49'W (D.H. 28)

Joanne Leveille
March, 1977

4c. Chemistry of Oil Shale Ash (Spent Shale)

P. Salib, 1983. Demonstration: Retorting of New Brunswick Oil Shales in a Pilot Scale Retort. New Brunswick Department of Natural Resources, Mineral Development Branch, Open File Report 83-7, Pages 14, 24.

TABLE 2: ULTIMATE AND ASH ANALYSIS OF LITHOTYPES

	Upper Shale	Albert Mines Zone	Clay Marlstone Zone	Dolomite Marlstone Zone
Utimate Analysis: wt%				
Organic Carbon	2.75	7.40	6.18	7.25
Inorganic Carbon	3.07	3.45	2.97	1.70
Hydrogen	0.83	1.26	1.07	1.05
Nitrogen	0.21	0.15	0.07	0.24
Sulphur	0.77	0.82	0.73	0.67
Oxygen	10.67	10.48	9.98	9.25
Ash	81.70	76.44	79.00	79.84
Ash Analysis: wt%				
Na_2O	3.60	1.72	2.40	2.65
K_2O	3.43	2.26	2.32	2.43
CaO	10.22	11.84	9.26	8.10
MgO	5.62	5.77	6.60	5.82
Fe_2O_3	7.79	7.91	8.01	8.08
Al_2O_3	24.48	19.64	20.39	21.58
SiO_2	44.86	50.86	51.02	51.34

TABLE 7: CARBON ANALYSIS OF FRESH AND SPENT SHALE SAMPLES

Carbon wt%	Fresh Shale Blend	Spent Shale from Tests 1	2	3	4
Total Carbon	9.34	2.20	4.06	3.42	2.41
Organic Carbon	6.72	0.91	1.91	1.71	0.93
Inorganic Carbon	2.62	1.29	2.15	1.71	1.48

Section 5

Trace Element Chemistry of Oil-Shale Ash

5a. Trace Element Chemistry of Oil Shale Ash

D. Abbott, 1970. Chemical Composition of New Brunswick Rocks, Minerals and Ores. Research and Productivity Council, Minerals and Material Sciences Department, Record 9, Pages 99-100.

TABLE 15 - BITUMINOUS SHALE ASHES

Cu decreasing

	1	2	3	4	5	6	7	8	9
Rock Name	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash
Locality	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.
Approx. Co-ords.	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W
Reference	Abbott & Barnett, 1968 5	Abbott & Barnett, 1968 6	Abbott & Barnett, 1968 2	Abbott & Barnett, 1968 4	Abbott & Barnett, 1968 1	Abbott & Barnett, 1968 3	Abbott & Barnett, 1968 14	Abbott & Barnett, 1968 13	Abbott & Barnett, 1968 10
Cu	0.014	0.011	0.009	0.009	0.008	0.008	0.008	0.007	0.007
Ge									
Mo	0.010	0.003	0.006	0.005	0.007	0.006	0.013	0.005	0.003
Ni	0.007	0.006	0.005	0.004	0.004	0.004	0.003	0.004	0.004
V	0.028	0.024	0.020	0.020	0.024	0.033	0.027	0.029	0.022

TABLE 15 - BITUMINOUS SHALE ASHES

Cu decreasing

	10	11	12	13	14
Rock Name	Shale Ash	Shale Ash	Shale Ash	Shale Ash	Shale Ash
Locality	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.	Albert Mines, Alb. Co.
Approx. Co-ords.	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W	45° 52' N 64° 40' W
Reference	Abbott & Barnett, 1968 9	Abbott & Barnett, 1968 11	Abbott & Barnett, 1968 8	Abbott & Barnett, 1968 12	Abbott & Barnett, 1968 7
Cu	0.007	0.006	0.006	0.005	0.004
Ge					
Mo	0.006	0.003	0.004	0.004	0.004
Ni	0.007	0.005	0.004	0.002	0.002
V	0.019	0.026	0.022	0.034	0.038

5b. Trace Element Chemistry of Oil Shale Ash

D. Abbott and D.E. Barnett, 1968. Composition of Oil Shale and Coal Ashes, New Brunswick. Research and Productivity Council, Minerals and Material Sciences Department, Research Note 14, Page 10.

TABLE 3

PRECISE DETERMINATION OF SELECTED ELEMENTS (WT. %)

	Vanadium	Nickel	Molybdenum	Copper	Germanium
Shale Ash					
1	0.024	0.004	0.007	0.008	
2	0.020	0.005	0.006	0.009	
3	0.033	0.004	0.006	0.008	
4	0.020	0.004	0.005	0.009	
5	0.028	0.007	0.010	0.014	
6	0.024	0.006	0.003	0.011	
7	0.038	0.002	0.004	0.004	
8	0.022	0.004	0.004	0.006	
9	0.019	0.007	0.006	0.007	
10	0.022	0.004	0.003	0.007	
11	0.026	0.005	0.003	0.006	
12	0.034	0.002	0.004	0.005	
13	0.029	0.004	0.005	0.007	
14	0.027	0.003	0.013	0.008	
Albertite					
15	0.085	7.07	0.84	0.032	0.025
Coal ash					
16	0.020	0.024	0.032	0.015	0.017
17	0.019	0.016	0.032	0.026	0.005
18	0.017	0.019	0.022	0.012	0.021
19	0.020	0.011	0.020	0.019	0.025
20	0.019	0.010	0.018	0.016	
21	0.013	0.006	0.010	0.009	0.016
22	0.020	0.005	0.010	0.012	0.007
23	0.012	0.007	0.012	0.018	0.001
24	0.011	0.006	0.020	0.011	0.003

Section 6

Ultimate Analyses of Oil Shale

6a. Ultimate Analyses of Oil Shale

R. Boorman, P. Salib, I. Wilkomirsky, R. Salter and R. Gilders, 1982. Design Concepts and Preliminary Economics for Coal/Oil Shale Combustion Retort Systems. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-28, Page A-4.

TABLE A - 2

ULTIMATE ANALYSES OF OILSHALES AND COAL (WT%)

Sample		C	H	N	S	Ash	Moisture	O
1. Coal (-8 mesh)	sample a	56.6	4.11	0.43	7.35	31.22	0.20	0.1
Tests OSC -13 to OSC -16c	sample b	58.9	4.05	0.46	7.25	28.48	0.05	0.86
2. Oil Shale (-50 +200 mesh)	sample a	14.16	1.57	< 0.2	2.35	73.11	0.27	8.54
Test OSC -13	sample b	14.20	1.52	< 0.2	2.25	73.19	0.26	6.58
3. Oil Shale (-20 +100 mesh)	sample a	11.53	1.39	< 0.2	0.90	76.66	0.34	9.18
Tests OSC -16a to OSC -16c	sample b	11.62	1.32	< 0.2	0.78	75.70	0.31	10.27
4. Coal (-¼" +20 mesh)	sample a	59.4	4.01	0.45	9.00	28.51	0.36	< 0.1
Tests OSC -17a to OSC -18c	sample b	60.52	4.06	0.45	8.40	29.07	0.44	< 0.1
5. Oil Shale (-8 +50 mesh)	sample a	10.22	1.22	<0.2	1.00	77.87	0.12	9.57
Tests OSC -17a to OSC -18c	sample b	10.35	1.26	<0.2	0.90	77.29	0.12	10.08
6. Oil Shale (-20 + 100 mesh)	sample a	14.21	1.57	<0.02	0.85	73.20	0.18	9.99
Tests OSC-14 to OSC-15b								

6b. Ultimate Analyses of Oil Shale

R.D. Gilders and R.S. Salter, 1982. Fluidized Bed Combustion of New Brunswick High Sulphur Coal and Oil Shale. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-9, Page 9.

TABLE 1
Bulk Samples Ultimate Analyses(WT % Dry)

#	Sample	Mineral Carbon	Organic Carbon	Hydrogen	Sulphur	Oxygen	Nitrogen	Ash	Ca**	Mg **	Na**
1	Oil Shale	2.85	12.69	1.98	1.13	7.93	<0.20	72.60	7.3	1.3	0.2
*1a	Oil Shale	2.91	13.13	2.02	1.11	7.29	<0.20	72.72	7.5	1.4	0.1
2	Coal	<1	49.77	3.53	6.80	8.30	<0.20	30.40			
*2a	Coal	<1	54.26	3.83	6.90	0.29	<0.20	33.52			

* 1a is a duplicate sample of 1.

2a is a duplicate sample of 2.

** Weak acid soluble species, ie. present as carbonates in shale.

6c. Ultimate Analyses of Oil Shale

P. Salib, 1983. Demonstration: Retorting of New Brunswick Oil Shales in a Pilot Scale Retort. New Brunswick Department of Natural Resources, Mineral Development Branch, Open File Report 83-7, Page 14.

TABLE 2: ULTIMATE AND ASH ANALYSIS OF LITHOTYPES

	Upper Shale	Albert Mines Zone	Clay Marlstone Zone	Dolomite Marlstone Zone
Utimate Analysis: wt%				
Organic Carbon	2.75	7.40	6.18	7.25
Inorganic Carbon	3.07	3.45	2.97	1.70
Hydrogen	0.83	1.26	1.07	1.05
Nitrogen	0.21	0.15	0.07	0.24
Sulphur	0.77	0.82	0.73	0.67
Oxygen	10.67	10.48	9.98	9.25
Ash	81.70	76.44	79.00	79.84
Ash Analysis: wt%				
Na_2O	3.60	1.72	2.40	2.65
K_2O	3.43	2.26	2.32	2.43
CaO	10.22	11.84	9.26	8.10
MgO	5.62	5.77	6.60	5.82
Fe_2O_3	7.79	7.91	8.01	8.08
Al_2O_3	24.48	19.64	20.39	21.58
SiO_2	44.86	50.86	51.02	51.34

6d. Ultimate Analyses of Oil Shale

J. Synnott and R. Salter, 1983. Modifications of Existing Testing Facilities, Optimization of Hydroretorting Conditions and Assessment of Canadian Oil Shales as Source of Synthetic Fuels. The Research and Productivity Council, Mineral Development and Processing, Report Number MDP/83/12, Page 25.

TABLE 3

COMPOSITION OF RAW OIL SHALES
(wt % - dry basis)

Samples	Mineral Carbon	Organic Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	BTU/lb
NB-1	3.65	10.88	1.61	0.14	0.52	12.23	2220
NB-2a	1.33	13.57	2.23	0.17	0.25	7.29	2528
NB-2b	0.85	3.48	1.30	0.04	0.29	8.01	680
NB-3	1.02	12.15	1.88	0.12	0.12	8.20	2365
NB-4	1.89	13.20	2.21	0.13	0.15	11.82	2514
NB-5	5.78	10.83	2.43	0.17	0.19	8.14	2994
NB-6	6.41	7.65	1.49	0.06	<0.01	15.01	1676
NB-7	6.12	12.62	2.65	0.07	<0.01	20.20	2500
NB-8	7.65	4.73	0.90	0.04	0.08	20.31	635
NB-9	2.59	14.52	2.32	0.17	<0.01	5.59	2948
NB-10	1.28	7.78	0.83	0.04	0.04	11.06	1000
NB-11	1.73	17.01	2.20	0.24	1.44	2.12	3701
NB-12	1.10	12.66	1.46	0.11	0.76	4.70	2323
NB-13	2.83	8.18	1.18	0.03	0.56	7.13	1676
NB-14	4.60	4.13	0.71	0.03	0.95	9.16	889
NB-15	3.35	1.22	0.30	0.06	0.86	6.60	287
NB-16	3.01	25.33	3.35	0.45	0.48	7.53	5320

Section 7

Organic Carbon Analyses of Oil Shale

7a. Organic Carbon Analyses of Oil Shale

R. Boorman, P. Salib, I. Wilkomirsky, R. Salter and R. Gilders, 1982. Design Concepts and Preliminary Economics for Coal/Oil Shale Combustion Retort Systems. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-28, Page A-4.

TABLE A - 2

ULTIMATE ANALYSES OF OILSHALES AND COAL (WT%)

Sample		C	H	N	S	Ash	Moisture	O
1. Coal (-8 mesh)	sample a	56.6	4.11	0.43	7.35	31.22	0.20	0.1
Tests OSC -13 to OSC -16c	sample b	58.9	4.05	0.46	7.25	28.48	0.05	0.86
2. Oil Shale (-50 +200 mesh)	sample a	14.16	1.57	< 0.2	2.35	73.11	0.27	8.54
Test OSC -13	sample b	14.20	1.52	< 0.2	2.25	73.19	0.26	6.58
3. Oil Shale (-20 +100 mesh)	sample a	11.53	1.39	< 0.2	0.90	76.66	0.34	9.18
Tests OSC -16a to OSC -16c	sample b	11.62	1.32	< 0.2	0.78	75.70	0.31	10.27
4. Coal (-¼" +20 mesh)	sample a	59.4	4.01	0.45	9.00	28.51	0.36	< 0.1
Tests OSC -17a to OSC -18c	sample b	60.52	4.06	0.45	8.40	29.07	0.44	< 0.1
5. Oil Shale (-8 +50 mesh)	sample a	10.22	1.22	<0.2	1.00	77.87	0.12	9.57
Tests OSC -17a to OSC -18c	sample b	10.35	1.26	<0.2	0.90	77.29	0.12	10.08
6. Oil Shale (-20 + 100 mesh)	sample a	14.21	1.57	<0.02	0.85	73.20	0.18	9.99
Tests OSC-14 to OSC-15b								

7b. Organic Carbon Analyses of Oil Shale

R.D. Gilders and R.S. Salter, 1982. Fluidized Bed Combustion of New Brunswick High Sulphur Coal and Oil Shale. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-9, Page 9.

TABLE 1
Bulk Samples Ultimate Analyses(WT % Dry)

#	Sample	Mineral Carbon	Organic Carbon	Hydrogen	Sulphur	Oxygen	Nitrogen	Ash	Ca**	Mg**	Na**
1	Oil Shale	2.85	12.69	1.98	1.13	7.93	<0.20	72.60	7.3	1.3	0.2
*1a	Oil Shale	2.91	13.13	2.02	1.11	7.29	<0.20	72.72	7.5	1.4	0.1
2	Coal	<1	49.77	3.53	6.80	8.30	<0.20	30.40			
*2a	Coal	<1	54.26	3.83	6.90	0.29	<0.20	33.52			

* 1a is a duplicate sample of 1.

2a is a duplicate sample of 2.

** Weak acid soluble species, ie. present as carbonates in shale.

7c. Organic Carbon Analyses of Oil Shale

G. Macauley and F.D. Ball, 1982. Oil Shales of the Albert Formation, New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-12, Pages 45-48, 166-169.

variations are considered attributable to sampling methods and to present day improvement in analytical technique rather than to loss of hydrocarbon from the core by weathering.

Water Yield: The high water yield of the clay marlstone zone in the Albert Mines area (Fig. 4) provided the first significant clue to the zonal definition of the oil shale interval. Because of the near-surface position of this zone at some locations, in conjunction with the abundant brecciation and faulting, downward movement of surface waters was suspected, but the relationship of higher water yields to the shalier (greater clay) lithotypes was readily apparent when all logs had been prepared.

If surface waters had been involved, the analytical data should have changed since the cores were cut; however, the excellent correlation of the new water yield data to older analyses, in conjunction with the clay mineralogy data, confirms the water yield as a by-product of clay disintegration during pyrolysis.

Correlations westerly and easterly of the Albert Mines area were based initially on recognition of the higher water yield zone, especially at AtlanticRichfield Boudreau 1, Can. Oxy. Rosevale 1, and AtlanticRichfield Urney 1. The underlying dolomite marlstones contain very little water, whereas the laminated marlstones are medial, having less water than the zones with greater clay, but generally more than the dolomite marlstones.

Organic Carbon

Analyses for total organic carbon content were conducted commercially in conjunction with the Rock-eval pyrolyses. Total carbon content was also determined at the Institute of

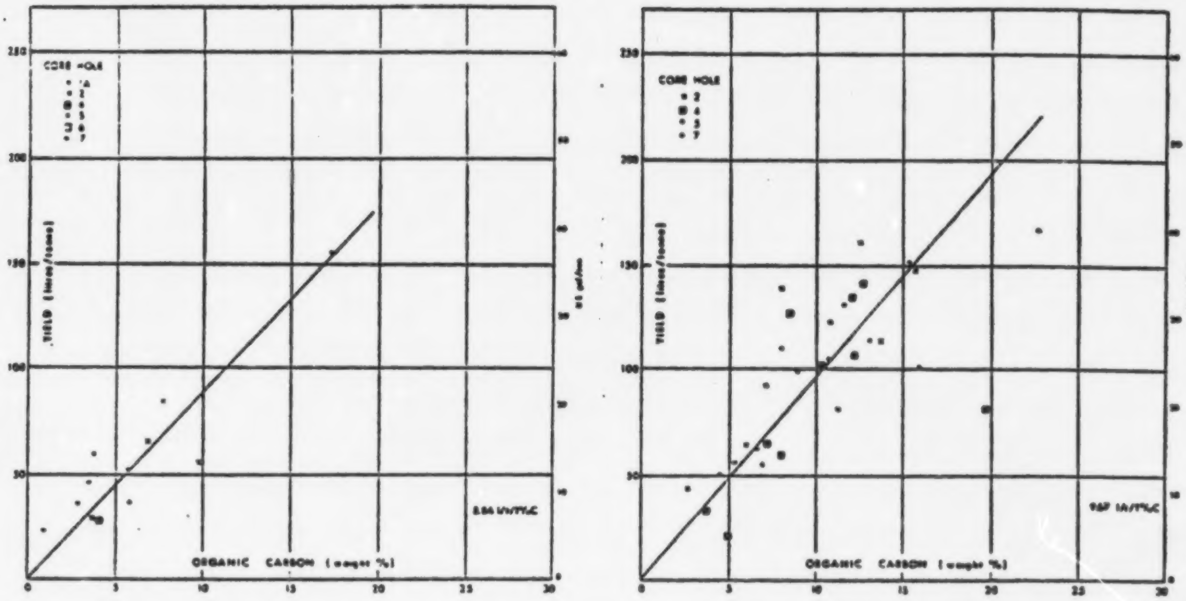
Sedimentary and Petroleum Geology in Calgary. Some variations were anticipated due to sampling, but the Institute of Sedimentary and Petroleum Geology data averaged 120% of the commercially reported values (Appendix 4). The generally higher Institute of Sedimentary and Petroleum Geology values have here been used.

When plotted against organic carbon values, yields from 129 samples averaged 8.67 litres/tonne (2.08 U.S. gallons/ton) per 1% organic carbon, basically without deviation from a straight line relationship in any quantity range.

On closer examination, some variation is evident for the lithologic zones of the Albert Mines area. Visually averaged plots indicate a maximum yield/1% organic carbon of 9.67 litres/tonne in the laminated marlstones of the Albert Mines zone, decreasing to 9.00 and 8.84 litres/tonne in the clay marlstone and upper zones, and further to 8.51 litres/tonne in the dolomite marlstone (Figs. 9a to d). Undoubtedly these results reflect the ease with which kerogen can be retorted relative to the degree of laminar development, such as the disseminated flecks common to dolomite marlstones (Plate 2.a) in contrast to the excellent laminar types (Plate 2.d). The actual yield variation across the zones is not great, as the lowest is 88% of the highest.

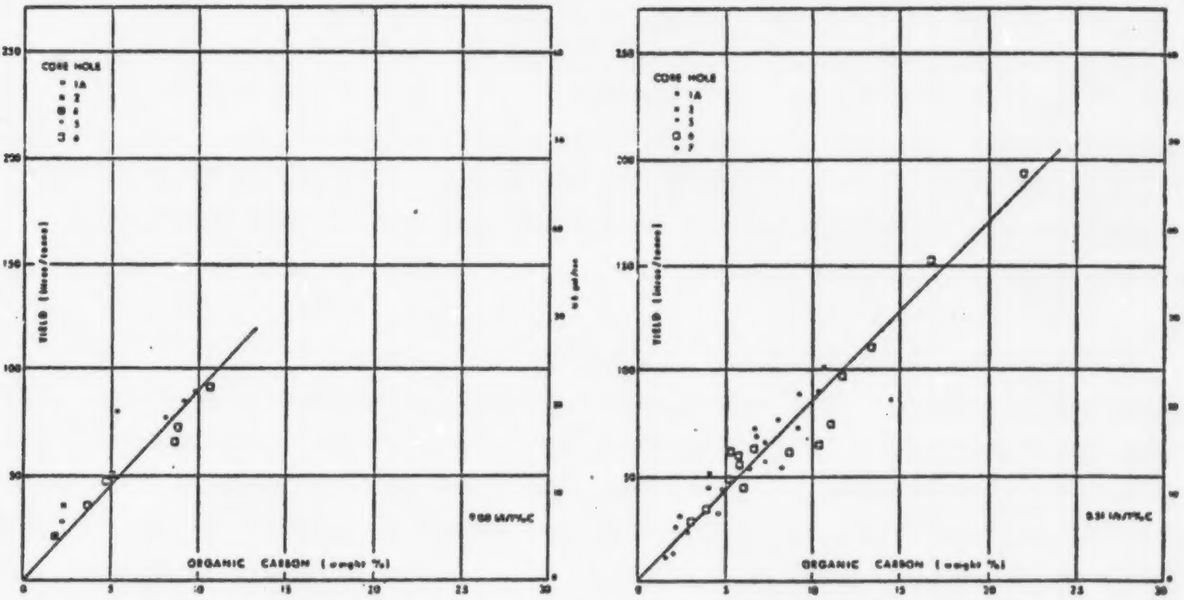
Insufficient data are available to assess properly lithologic zones in the other areas. Average yields from all samples are 8.40 litres/tonne at AtlanticRichfield Boudreau 1 and 8.00 litres/tonne at Can. Oxy. Rosevale 1, both per 1% organic carbon (Figs. 10a, b). In these areas, from the few data, both total yields and yields relative to organic carbon are less than in the Albert Mines area.

From all Albert Mines data, the average organic carbon content is 7.09%, ranging to a maximum 29.40% which



a: Upper Zone

b: Albert Mines Zone

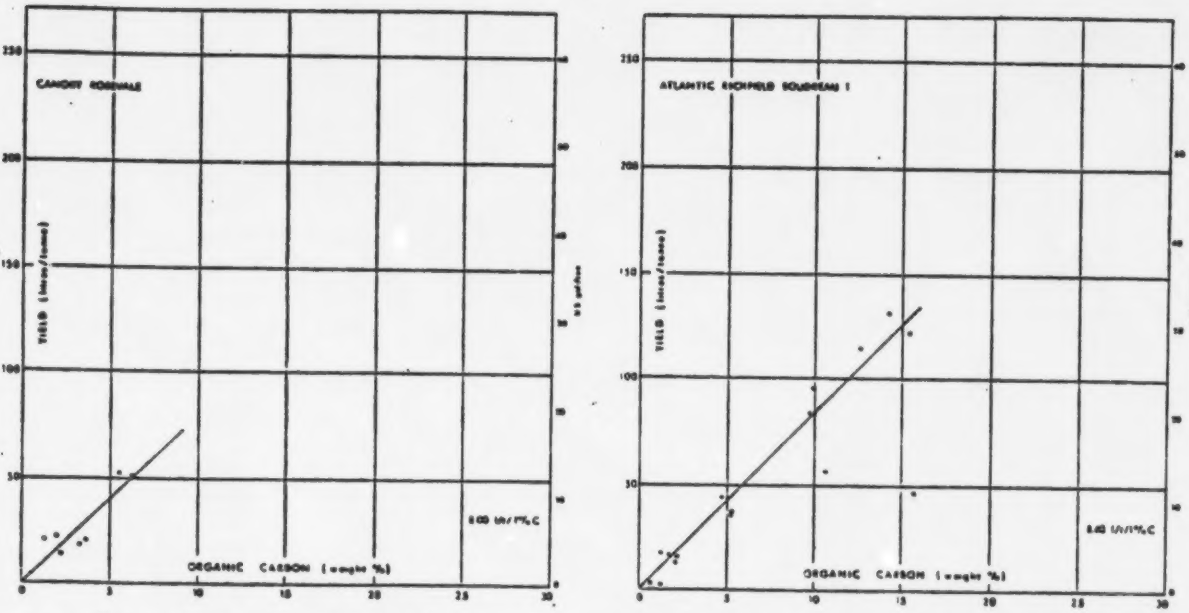


c: Clay Marlstone Zone

d: Dolomite Marlstone Zone

Figure 9: Fischer Assay yield vs. organic carbon content, Albert Mines area

assayed 263 litres/tonne. At Boudreau, average organic carbon is 6.44%, and is even lower, 3.20%, from the limited Rosevale data.



a: Can. Oxy. Rosevale 1

b: AtlanticRichfield Boudreau 1

Figure 10: Fischer Assay yield vs. organic carbon content

Rock-eval Pyrolyses

Several new factors, not previously investigated for the Albert oil shales, can be interpreted from the Rock-eval pyrolyses. Both the kerogen type and the maturation stage of the kerogen are significant to the quality and quantity of the recovered shale oil. The interpreted "petroleum potential" is directly comparable to Fischer assays, but also differentiates petroleum versus kerogen components of the oil shale product. Appendix 4 lists all data involved in the Rock-eval process.

Kerogen: Espitalie *et al.* (1977) report that the "hydrogen index" (mg. HC/g. org.C) and "oxygen index"

APPENDIX 4A

FISCHER ASSAY RESULTS

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
AtlanticRichfield Albert Mines 1A								
1	240.8	CM	2.12	78.0	1.8	0.913	8.14	10.28
2	249.6	CM	1.92	79.6	1.5	0.913	5.54	8.26
3	292.0	DM	2.19	65.9	0.8	0.911	8.00	11.16
4	305.1	DM	1.79	56.7	0.5	0.909	8.07	10.87
Canadian Occidential Petroleum Albert Mines 2								
1	20.4	US	2.07	97.2	2.2	0.869	9.84	11.48
2	44.8	US	2.01	28.4	1.6	0.870	3.71	7.76
3	69.2	US	2.19	65.5	2.2	0.876	6.83	8.25
4	89.9	AM	2.19	148.9	1.4	0.874	15.68	18.41
5	107.9	AM	2.11	93.0	1.4	0.870	7.14	9.74
5A	110.9	AM	2.34	44.2	1.1	0.870	2.71	11.66
6	125.0	AM	1.81	118.8	1.5	0.878	13.61	17.57
6A	128.6	AM	1.93	100.1	1.8	0.878	8.96	11.56
7	140.8	AM	1.99	65.1	0.7	0.879	6.03	12.77
8	166.4	AM	1.67	162.2	1.2	0.876	12.27	15.23
9	178.6	AM	1.89	140.5	1.1	0.878	8.24	11.27
9A	238.0	CM	*	38.8	3.5	0.877	2.46	4.98
10	241.1	DM	2.07	100.9	1.6	0.880	10.66	12.87
11	244.4	DM	2.37	50.5	2.4	0.877	4.07	6.92
Canadian Occidental Petroleum Albert Mines 4								
1	415.1	US	2.39	27.9	2.6	0.858	4.10	6.50
2	431.0	AM	2.18	126.8	1.7	0.870	8.35	10.33
3	431.9	AM	1.95	142.6	1.6	0.879	12.46	14.42
4	445.9	AM	2.61	22.5	0.5	0.877	5.12	11.38
5	450.8	AM	2.03	134.7	0.9	0.880	11.98	15.06
6	456.3	AM	2.28	65.5	1.9	0.879	7.25	9.06
7	465.4	AM	2.31	59.2	1.5	0.879	7.94	10.72
8	474.9	AM	2.26	102.2	1.0	0.877	10.27	13.20
9	476.4	AM	2.23	82.6	1.1	0.874	19.64	21.90
10	484.6	AM	2.10	108.0	0.8	0.878	12.20	15.21
11	495.6	AM	2.45	33.4	1.7	0.877	3.70	6.06
12	502.3	AM	2.27	57.1	1.0	0.876	1.91	11.08
13	517.6	CM	*	20.4	4.0	0.875	1.91	3.72
Canadian Occidental Petroleum Albert Mines 5								
1	78.0	US	1.88	155.5	1.4	0.875	17.14	18.35
2	142.6	US	2.34	59.6	1.7	0.876	3.82	10.00
3	146.3	US	2.68	23.8	0.8	0.872	0.96	10.25
4	172.2	US	2.44	37.1	1.2	0.874	5.47	9.32
5	181.4	US	2.59	36.3	1.4	0.875	2.96	10.25

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
6	192.3	US	1.87	83.8	1.5	0.878	7.61	10.35
7	197.8	AM	2.07	123.4	1.3	0.877	10.81	14.97
8	202.1	AM	2.11	105.1	1.5	0.876	10.50	14.03
9	208.2	AM	1.85	132.6	2.1	0.880	11.37	13.41
10	233.2	AM	1.83	115.5	1.8	0.878	13.17	14.54
11	238.4	AM	1.99	83.0	1.6	0.882	11.30	14.14
12	253.0	AM	1.70	167.2	1.6	0.880	22.41	24.39
13	256.6	AM	2.06	148.9	1.2	0.883	15.33	18.13
14	267.0	AM	1.82	102.2	0.9	0.887	15.77	19.37
15	268.8	AM	1.35	262.7	1.8	0.890	29.31	31.16
16	279.5	AM	1.89	111.3	1.1	0.890	8.26	10.47
17	282.5	AM	1.98	60.5	1.0	0.892	7.10	11.17
18	285.9	AM	2.35	50.5	1.2	0.891	4.54	8.63
19	345.9	CM	2.19	84.7	1.2	0.893	9.17	12.58
20	363.9	CM	1.97	90.1	0.9	0.888	9.76	11.52
21	399.9	DM	2.13	28.8	0.4	0.892	2.24	8.02
22	414.5	DM	2.04	75.9	0.4	0.890	8.25	11.56
23	447.1	DM	2.19	72.6	0.5	0.894	7.80	12.85
24	487.7	DM	2.40	33.4	0.2	0.892	3.78	7.48
25	504.1	DM	2.24	88.0	0.2	0.893	9.16	12.45
26	535.2	DM	2.38	44.6	0.2	0.889	4.21	7.47
27	591.6	DM	2.08	43.8	0.4	0.894	4.95	8.15
28	598.0	DM	2.07	85.5	0.5	0.889	14.57	18.90
29	606.6	DM	2.35	22.9	0.3	0.895	2.93	7.43
30	652.3	DM	2.06	72.6	0.3	0.899	9.23	12.09
31	656.8	DM	2.16	53.6	0.3	0.889	6.50	9.93
32	664.5	DM	2.40	31.7	0.4	0.880	4.61	6.93
33	710.2	DM	2.50	70.4	0.7	0.871	2.48	4.18
34	737.6	DM	2.02	69.4	0.3	0.871	6.90	10.36
35	743.7	DM	2.22	26.3	0.2	0.869	2.44	5.73
Canadian Occidental Petroleum Albert Mines 6								
1	68.6	CM	2.01	47.5	1.4	0.869	5.00	7.99
2	77.1	CM	2.02	49.6	2.5	0.922	4.97	7.75
3	81.7	CM	2.17	35.4	2.2	0.920	3.74	8.55
4	91.5	CM	2.12	71.7	2.2	0.919	8.93	9.83
5	103.6	CM	2.28	91.3	1.4	0.921	10.52	12.16
6	121.9	DM	2.23	65.9	0.4	0.919	8.67	12.01
7	132.0	DM	2.14	111.8	0.5	0.918	13.33	14.80
8	143.6	DM	2.12	96.7	0.5	0.919	11.71	15.24
9	153.3	DM	2.37	48.8	0.9	0.913	5.45	7.57
10	182.3	DM	2.37	58.8	0.3	0.914	5.86	9.91
11	185.3	DM	2.24	62.6	0.3	0.904	6.96	10.31
12	188.1	DM	2.29	61.7	0.4	0.904	5.37	9.73
13	194.8	DM	2.43	33.8	0.2	0.899	3.93	8.03
14	199.3	DM	2.14	62.1	0.6	0.901	8.95	11.69
15	204.2	DM	1.89	157.2	0.5	0.903	17.00	19.40
16	214.9	DM	2.43	43.8	0.2	0.904	6.24	10.70

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
17	237.7	DM	2.53	55.5	0.4	0.899	6.07	8.92
18	242.0	DM	1.22	193.9	0.6	0.897	22.12	26.00
19	246.9	DM	2.49	28.8	0.2	0.895	3.16	7.01
20	256.0	DM	2.26	64.2	0.4	0.899	10.47	14.27
21	283.2	DM	2.15	74.6	0.4	0.901	11.26	13.18
Canadian Occidental Petroleum Albert Mines 7								
1	32.0	HB	2.38	45.9	0.7	0.891	3.52	9.77
2	56.7	HB	2.28	52.1	0.7	0.897	5.77	7.49
3	108.8	AM	2.35	57.5	0.4	0.891	5.53	7.41
4	115.8	AM	2.31	63.0	0.2	0.887	5.56	7.97
5	158.8	DS	2.44	11.3	2.1	0.889	1.62	3.23
5A	212.8	RH	2.43	25.0	0.4	0.887	1.80	3.28
6	334.4	RH	2.12	90.5	0.5	0.884	10.31	13.44
7	357.8	DS	2.36	53.4	0.4	0.884	8.14	10.38
8	409.0	RH	2.54	12.5	0.4	0.879	3.20	5.23
9	442.3	RH	2.54	13.3	0.2	0.888	2.11	5.42
AtlanticRichfield Boudreau 1								
1	132.9	HB	2.59	3.8	1.4	0.914	0.56	1.68
2	147.8	HB	2.25	16.8	0.2	0.908	1.57	3.76
3	195.1	US	2.52	17.1	1.6	0.914	1.19	3.85
4	261.5	US	2.52	16.3	1.7	0.909	2.30	2.87
5	289.0	US	2.56	2.5	2.1	0.914	1.24	3.53
6	302.8	AM	2.59	44.2	0.9	0.917	4.49	7.20
7	315.2	AM	2.55	35.0	0.4	0.914	5.03	9.20
8	371.9	AM	2.25	83.8	0.6	0.916	9.52	12.57
9	375.8	AM	2.39	37.1	1.0	0.920	5.25	9.10
10	379.2	AM	2.05	123.8	0.7	0.918	15.31	18.10
11	433.1	DM	2.14	96.3	0.8	0.917	9.72	11.85
12	443.2	DM	2.09	132.6	0.9	0.918	13.99	18.86
13	475.5	DM	2.65	12.9	0.1	0.921	1.97	6.23
14	481.3	DM	2.29	56.7	0.5	0.914	10.88	12.43
15	551.4	RH	1.95	115.1	0.5	0.912	12.65	15.52
AtlanticRichfield Dover 1A								
1	34.1	US	2.26	65.1	1.8	0.908	15.24	17.54
2	40.9	US	2.48	15.8	3.1	0.909	2.36	3.41
3	191.1	DM	2.28	42.1	2.0	0.910	5.56	9.74
4	198.7	DM	2.51	15.0	1.6	0.909	2.04	5.96
5	202.7	DM	2.26	85.1	1.3	0.906	11.09	14.73
Canadian Occidental Petroleum Rosevale 1								
A	310.9	HB	2.24	15.0	1.3	0.889	2.15	4.58
B	314.6	HB	*	0.0	3.2	0.909	1.62	2.06
1	512.7	HB	2.47	20.9	0.8	0.889	1.21	1.44
2	598.0	US	2.47	21.7	0.2	0.891	1.95	4.34
3	603.8	US	2.57	17.9	0.8	0.887	3.40	7.81

No.	Depth (m)	Zone	Bulk Density (gm/cc)	Yield (l/t)	Water (Wt.%)	Oil Gravity (gm/cc)	Organic Carbon (Wt.%)	Total Carbon (Wt.%)
4	612.6	AM	2.43	53.4	0.2	0.884	5.53	10.64
5	632.5	CM	2.43	21.3	2.3	0.884	3.57	6.04
6	635.8	CM	2.53	50.5	0.5	0.889	6.30	9.84
AtlanticRichfield Urney 1								
1	71.9	AM	2.29	7.5	0.4	0.906	1.88	6.18
2	99.2	AM	2.24	7.9	0.1	0.906	2.36	5.18
3	106.7	AM	2.28	12.1	0.5	0.906	2.50	6.03
4	228.9	DM	2.40	33.8	0.4	0.898	0.93	11.95

* unsuitable for analysis

7d. Organic Carbon Analyses of Oil Shale

P. Salib, 1983. Demonstration: Retorting of New Brunswick Oil Shales in a Pilot Scale Retort. New Brunswick Department of Natural Resources, Mineral Development Branch, Open File Report 83-7, Pages 14, 24.

TABLE 2: ULTIMATE AND ASH ANALYSIS OF LITHOTYPES

	Upper Shale	Albert Mines Zone	Clay Marlstone Zone	Dolomite Marlstone Zone
Utimate Analysis: wt%				
Organic Carbon	2.75	7.40	6.18	7.25
Inorganic Carbon	3.07	3.45	2.97	1.70
Hydrogen	0.83	1.26	1.07	1.05
Nitrogen	0.21	0.15	0.07	0.24
Sulphur	0.77	0.82	0.73	0.67
Oxygen	10.67	10.48	9.98	9.25
Ash	81.70	76.44	79.00	79.84
Ash Analysis: wt%				
Na_2O	3.60	1.72	2.40	2.65
K_2O	3.43	2.26	2.32	2.43
CaO	10.22	11.84	9.26	8.10
MgO	5.62	5.77	6.60	5.82
Fe_2O_3	7.79	7.91	8.01	8.08
Al_2O_3	24.48	19.64	20.39	21.58
SiO_2	44.86	50.86	51.02	51.34

TABLE 7: CARBON ANALYSIS OF FRESH AND SPENT SHALE SAMPLES

Carbon wt%	Fresh Shale Blend	Spent Shale from Tests 1	2	3	4
Total Carbon	9.34	2.20	4.06	3.42	2.41
Organic Carbon	6.72	0.91	1.91	1.71	0.93
Inorganic Carbon	2.62	1.29	2.15	1.71	1.48

7e. Organic Carbon Analyses of Oil Shale

J. Synnott and R. Salter, 1983. Modifications of Existing Testing Facilities, Optimization of Hydroretorting Conditions and Assessment of Canadian Oil Shales as Source of Synthetic Fuels. The Research and Productivity Council, Mineral Development and Processing, Report Number MDP/83/12, Page 25.

TABLE 3

COMPOSITION OF RAW OIL SHALES
(wt % - dry basis)

Samples	Mineral Carbon	Organic Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	BTU/lb
NB-1	3.65	10.88	1.61	0.14	0.52	12.23	2220
NB-2a	1.33	13.57	2.23	0.17	0.25	7.29	2528
NB-2b	0.85	3.48	1.30	0.04	0.29	8.01	680
NB-3	1.02	12.15	1.88	0.12	0.12	8.20	2365
NB-4	1.89	13.20	2.21	0.13	0.15	11.82	2514
NB-5	5.78	10.83	2.43	0.17	0.19	8.14	2994
NB-6	6.41	7.65	1.49	0.06	<0.01	15.01	1676
NB-7	6.12	12.62	2.65	0.07	<0.01	20.20	2500
NB-8	7.65	4.73	0.90	0.04	0.08	20.31	635
NB-9	2.59	14.52	2.32	0.17	<0.01	5.59	2948
NB-10	1.28	7.78	0.83	0.04	0.04	11.06	1000
NB-11	1.73	17.01	2.20	0.24	1.44	2.12	3701
NB-12	1.10	12.66	1.46	0.11	0.76	4.70	2323
NB-13	2.83	8.18	1.18	0.03	0.56	7.13	1676
NB-14	4.60	4.13	0.71	0.03	0.95	9.16	889
NB-15	3.35	1.22	0.30	0.06	0.86	6.60	287
NB-16	3.01	25.33	3.35	0.45	0.48	7.53	5320

Section 8

Chemistry or Characteristics of Albert Shale Oil

8a. Chemistry or Characteristics of Albert Shale Oil

G. Macauley, 1981. Geology of the Oil Shales of Canada. New Brunswick Department of Natural Resources, Geological Surveys Branch, Open File Report 81-23, Page 81.

Characteristics of Shale Oil

S.G. @ 60° F	0.861	API @ 60°F	32.8
Sulphur, % by wt.	0.75	Pour Point, °F	60

Approximate Summary

	% by volume	S.G.	Degrees A.P.I.	Saybolt Viscosity 100°F
Light gasoline	4.9	0.697	71.5	
Gasoline & Naptha	25.0	0.758	55.2	
Kerosene	5.7	0.823	40.4	
Gas oil	24.0	0.857	33.6	below 50
Non-viscous lubricating distillate	15.3	0.876 to 0.902	30.0 to 25.4	50-100
Viscous lubricating distillate	?			above 200
Residuum	19.5			
Distillation loss	0.7			

Rosevale:

Table 5 summarizes the core data from the 1942 Department of Mines activity in the Rosevale area, and is repeated from S.C. Ells (1948). Data from Atlantic-Richfield Rosevale #1 are added to the bottom of the table for comparison. A weighted average yield from 834 feet (254 metres) of analyzed core at the Atlantic-Richfield hole is 4.06 gallons/ton.

In all of the test holes, only limited footages had yields exceeding 10 gallons/ton (50 litres/tonne): the shale oil recoveries of this area are considerably less than at Albert Mines. Figure 17 illustrates the distribution of the core hole pattern, as provided by Ells and generalized along the outcrop trend. All the holes are presumed to be vertical as no inclinations are given. The beds are mapped with dips of less than 45°, but are definitely not flat-lying.

Published data are not sufficient to determine the degree of structural deformation in the cores, or whether a better zone, equivalent to that of the Albert Mines area, exists at Rosevale. If the oil shales are all one single lacustrine deposit, it is considered probable that the gross zonation can be carried across the entire area.

The shale oil quality at Rosevale is similar to that at Albert Mines, but is slightly heavier, S.G. 0.884 and API gravity 28.6, has slightly less sulphur at 0.58%, and has 2 to 4% less of each lighter fraction with

8b. Chemistry or Characteristics of Albert Shale Oil

G. Macauley and F.D. Ball, 1982. Oil Shales of the Albert Formation, New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-12, Pages 44-45.

Shale Oil Gravity: Specific gravity data for the recovered shale oil vary somewhat from the original assays to those of the present study. The more recent determinations are much more uniform throughout each borehole than are the widely fluctuating values plotted as histograms from the original data. This could represent a loss of bituminous phase by weathering since the cores were cut, but several zones show lower average specific gravity now, the inverse to that expected from organic deterioration. Some now also indicate generally higher specific gravity values. These differences may be attributed to crushing technique and possibly to present more efficient temperature control during the Fischer assay process.

From the original core data, the average specific gravity of the Frederick Brook oil shale interval in the Albert Mines area is 0.872 (30.77°, API), with very minimal changes from zone to zone (upper, 0.869/31.33°; Albert Mines, 0.876/30.02°; clay marlstone, 0.864/32.27°; dolomite marlstone, 0.874/30.40°). The zones with greater clay content yield slightly better quality shale oil but the variations are not particularly significant.

In the Urney-Rosevale and Boudreau-Dover areas (Fig. 5), yields are generally lower than at Albert Mines, and the oil specific gravities were often reported as "averaged" over thick intervals: probably the yields were generally too low to provide adequate sample for gravity determinations. At Can. Oxy. Rosevale, the more recent samples indicate an average S.G. at 0.890 (27.49°, API), somewhat lower than 0.907 (24.51°, API) from the core assays. In contrast, the initial results at AtlanticRichfield Dover 1A average 0.871 (30.96°, API) in contrast to the few samples of this study at a much higher 0.907 (24.51°, API) average specific gravity.

Because the present determinations range above and below those of the assays made when the core was fresh, the variations are considered attributable to sampling methods and to present day improvement in analytical technique rather than to loss of hydrocarbon from the core by weathering.

Water Yield: The high water yield of the clay marlstone zone in the Albert Mines area (Fig. 4) provided the first significant clue to the zonal definition of the oil shale interval. Because of the near-surface position of this zone at some locations, in conjunction with the abundant brecciation and faulting, downward movement of surface waters was suspected, but the relationship of higher water yields to the shalier (greater clay) lithotypes was readily apparent when all logs had been prepared.

If surface waters had been involved, the analytical data should have changed since the cores were cut; however, the excellent correlation of the new water yield data to older analyses, in conjunction with the clay mineralogy data, confirms the water yield as a by-product of clay disintegration during pyrolysis.

Correlations westerly and easterly of the Albert Mines area were based initially on recognition of the higher water yield zone, especially at AtlanticRichfield Boudreau 1, Can. Oxy. Rosevale 1, and AtlanticRichfield Urney 1. The underlying dolomite marlstones contain very little water, whereas the laminated marlstones are medial, having less water than the zones with greater clay, but generally more than the dolomite marlstones.

Organic Carbon

Analyses for total organic carbon content were conducted commercially in conjunction with the Rock-eval pyrolyses. Total carbon content was also determined at the Institute of

8c. Chemistry or Characteristics of Albert Shale Oil

P. Salib, 1983. Demonstration: Retorting of New Brunswick Oil Shales in a Pilot Scale Retort. New Brunswick Department of Natural Resources, Mineral Development Branch, Open File Report 83-7, Pages 23, 31, 36-45.

TABLE 6: SHALE OIL PROPERTIES

Test No.	Sample Location	Gravity		Viscosity CPS	Pour Point °C	Calorific Value BTU/lb	Sulphur wt%	Nitrogen wt%	Carbon wt%	Hydrogen wt%	C/H Ratio
		Specific	API								
1	Cyclone	0.8922	27.1	8.18	- 2	19,188	0.41	0.11	86.39	12.55	6.88
	Condenser	0.8254	39.9	2.30	-44	19,369	0.67	0.19	86.81	12.89	6.73
	ESP	0.8266	39.7	2.75	-41	19,210	0.56	0.12	85.36	12.12	7.09
2	Cyclone	0.9136	23.4	14.30	+ 7	18,830	0.61	0.33	86.80	12.83	6.77
	Condenser	0.8632	32.4	7.92	0	18,947	0.60	0.21	86.62	12.05	7.19
	ESP	0.8852	28.4	4.94	- 6	18,793	0.68	0.11	86.07	12.31	6.99
3	Cyclone	0.9716	14.1	150.00	+15	18,913	0.41	0.13	87.15	12.26	7.10
	Condenser	0.8806	29.2	9.30	+ 2	19,205	0.51	0.15	86.67	12.44	6.97
	ESP	0.8594	33.3	5.70	- 3	18,847	0.44	0.27	85.85	11.98	7.17
	Column	0.8624	32.6	9.15	+ 3	18,977	0.53	0.27	87.03	12.33	7.06
4	Cyclone	0.9170	22.8	124.00	+ 6	18,982	0.49	0.31	87.04	12.61	6.90
	Condenser	0.8672	31.7	10.00	+ 3	19,027	0.42	0.34	87.29	12.30	7.10
	ESP	0.8792	29.4	7.20	0	18,667	0.35	0.30	86.24	12.21	7.06
	Column	0.8780	29.7	7.20	+ 1	19,248	0.52	0.15	86.80	12.84	6.76

TABLE 8: COMPARISON OF SHALE OIL PROPERTIES WITH PRODUCTS FROM OTHER RETORTING PROCESSES*

Parameter	RPC	Arabian Light Crude	Dravo	Pharoho	Tosco II	Union B	Oxy-MIS	USBM**
Retort Method	Direct	-	Direct	Direct	Indirect	Indirect	Direct	Direct
API Gravity	33.3-14.1 41.1	34.7	20.8	19.3	21.2	22.7	24-25	21.2
Pour Point, °C	-8-+15	-26	29.4	29.4	26.7	15.6	10-18.3	29.4
Viscosity @100°F; CPS	5.70-150.00	5.5	75.0	78.5	27.1	98.0	15.8	18.1
Sulphur, wt%	0.35-0.61	1.71	0.98	0.71	0.67	0.9	0.64	2.12
Nitrogen, wt%	0.11-0.34	0.08	1.82	2.00	1.85	2.00	1.50	2.10
C/H Ratio	6.76-7.17	6.2	7.41	7.40	7.30	7.30	7.20	7.42

* source - reference 6
** source - reference 7

APPENDIX A
ANALYSIS OF PRODUCT OIL AND GAS

Oil Analysis

One of the methods commonly used for characterization of petroleum products is the American Society for Testing Materials (A.S.T.M.) distillation, which is simple batch distillation carried out according to the rigorously specified procedure given in the A.S.T.M. Book of Standards.

The results are usually reported in terms of the temperatures at which 10, 20, 30, etc., percent of the original charge has been distilled. Therefore, if a high percent was distilled at a low temperature, this indicates a light oil and the reverse is true.

In this study, however, chromotography has been used for the same purpose. Chromotograms of all product oils are shown in Figure A-1 to A-14. The area under each peak represents a hydrocarbon with a given boiling point. Also the chromotograph was calibrated so that the position of the peaks corresponding to straight chain saturated hydrocarbons were identified. These were the peaks marked on the chromotograms, the number given corresponds to the number of carbon atoms. Knowing the boiling points of these hydrocarbons, we were able to calculate the percentage of oil which boils within these temperature ranges, see Table A-1.

The table shows the weight percent of oil boiling below the indicated temperatures. The results are consistent with those given in Table 6. For example, oils from Test 1 are much lighter than the remaining tests. Also, within the same test the general trend, with few exceptions, is that the oil gets lighter as it progresses through the oil recovery train,i.e., cyclone, condenser, electro-static precipitation

TABLE A-1: BOILING POINTS OF OIL PRODUCTS

Oil Weight % Cumulative

Temp. (°C)	Test 1			Test 2			Test 3				Test 4			
	Cyclone	Condenser	ESP	Cyclone	Condenser	ESP	Cyclone	Condenser	ESP	Column	Cyclone	Condenser	ESP	Column
126	3.4	2.1	0.9	3.0	6.1	6.0	4.2	0.9	8.0	0.5	6.7	0.7	1.4	2.0
174	3.4	10.6	8.2	3.8	12.5	11.4	4.4	6.5	12.6	4.4	6.7	10.4	6.7	4.6
216	5.6	46.3	44.0	5.9	29.8	35.2	5.3	26.4	30.0	16.5	7.3	23.3	26.0	14.2
254	17.5	80.5	77.7	13.7	48.3	59.8	8.3	45.3	53.1	32.7	12.3	40.8	50.3	34.7
287	44.4	93.9	91.6	31.9	60.7	76.1	17.3	58.8	69.1	51.8	24.0	55.3	64.7	62.0
316	68.8	97.6	95.9	55.0	72.9	86.1	34.9	70.6	81.7	71.1	43.5	68.0	76.0	80.4
343	84.0	99.1	98.2	73.2	83.0	92.3	56.2	81.3	89.4	84.5	63.0	79.7	84.8	89.4
413	98.5	100.0	100.0	96.8	93.7	99.3	94.3	97.5	99.4	98.6	95.6	97.7	98.5	98.9

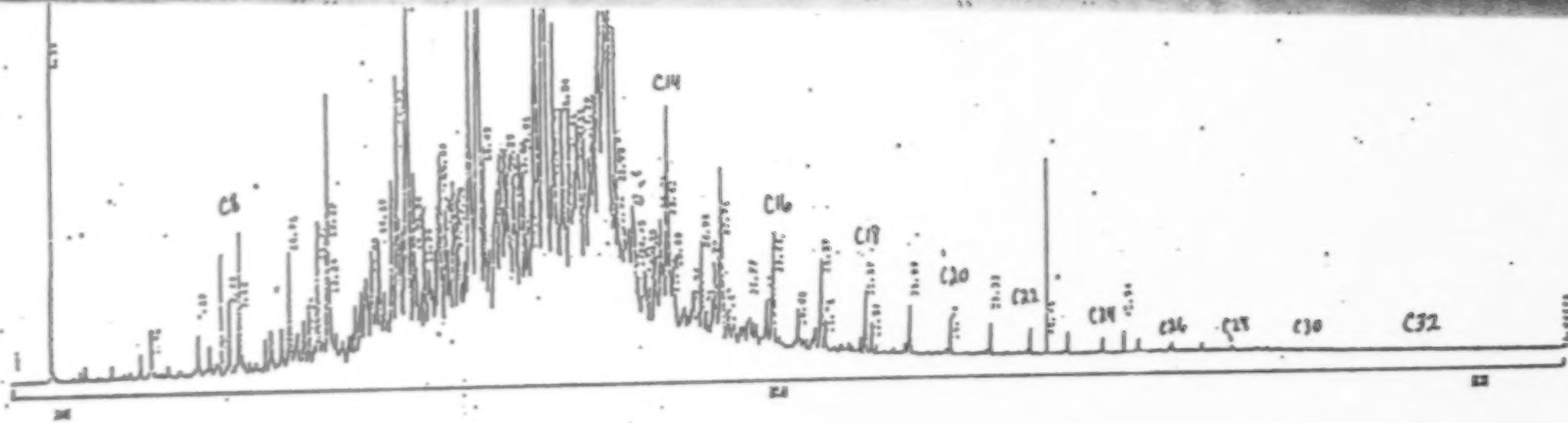


Figure A-1: Chromotogram for Test 1 (Cyclone)

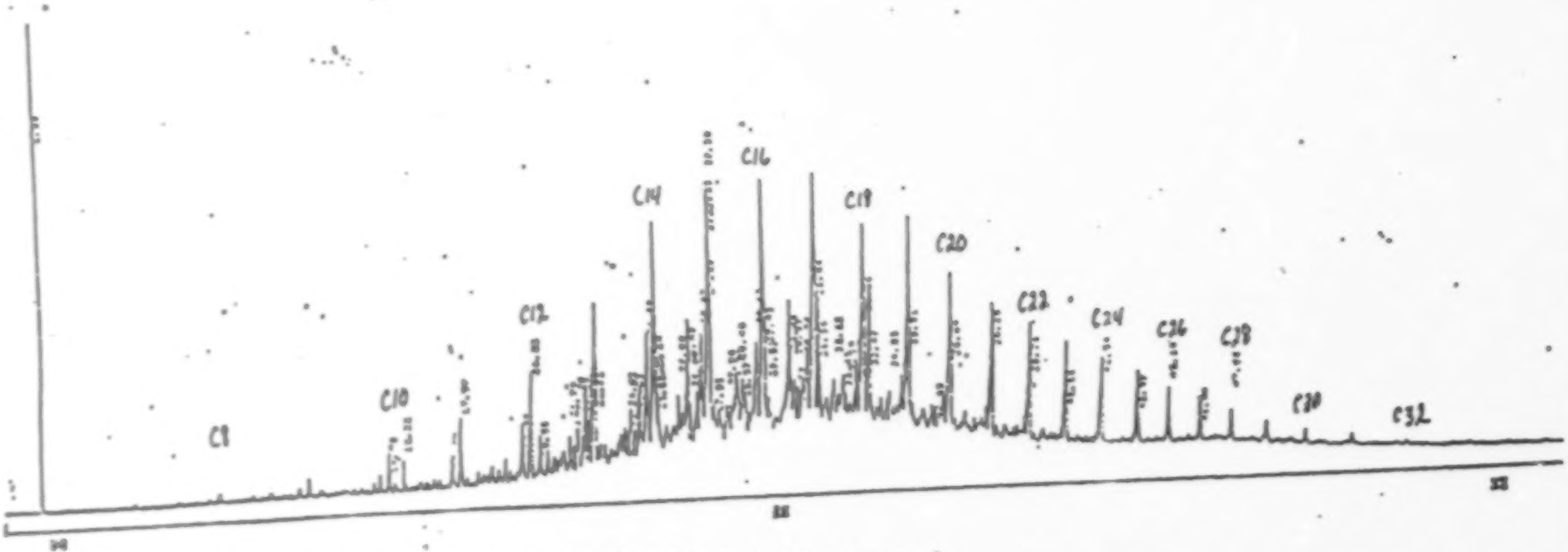


Figure A-2: Chromotogram for Test 1 (Condenser)

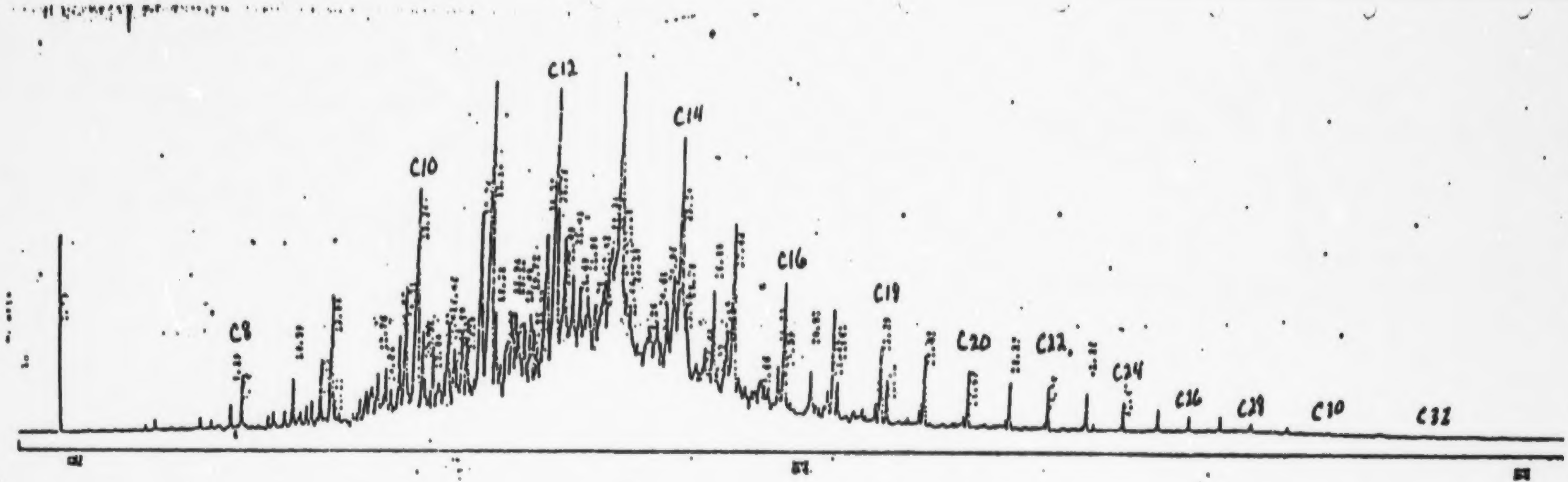


Figure A-3: Chromotogram for Test 1 (ESP)

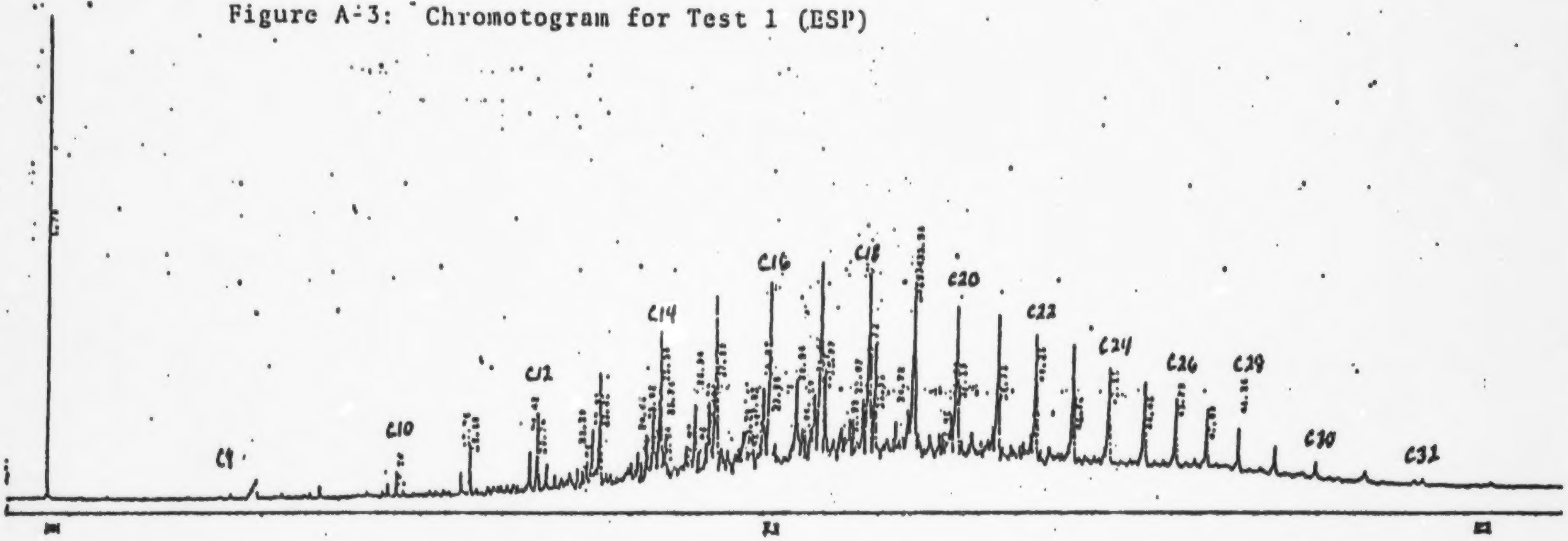


Figure A-4: Chromotogram for Test 2 (Cyclone)

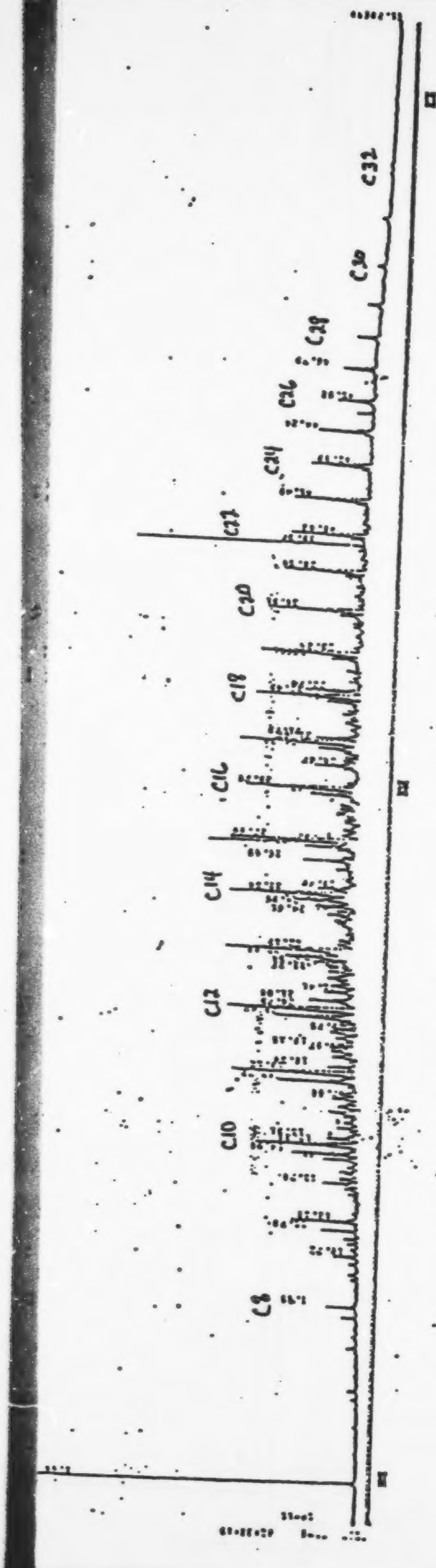


Figure A-5: Chromotogram for Test 2 (Condenser)

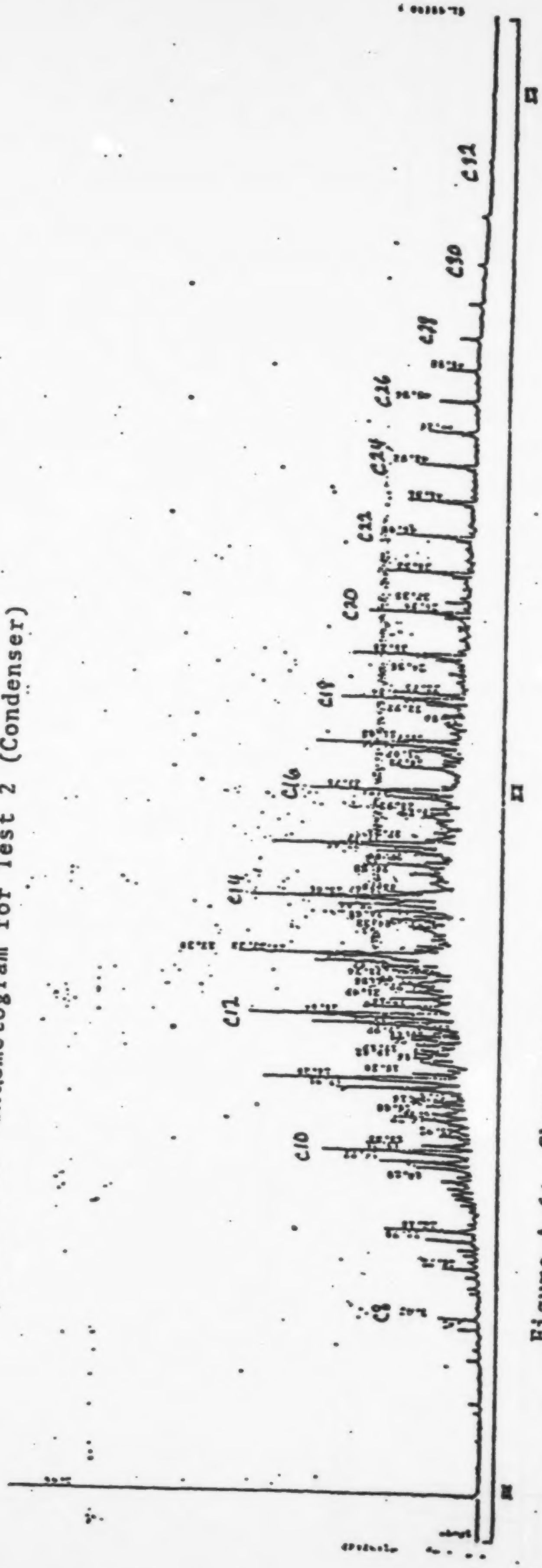


Figure A-6: Chromotogram for Test 2 (ESP)

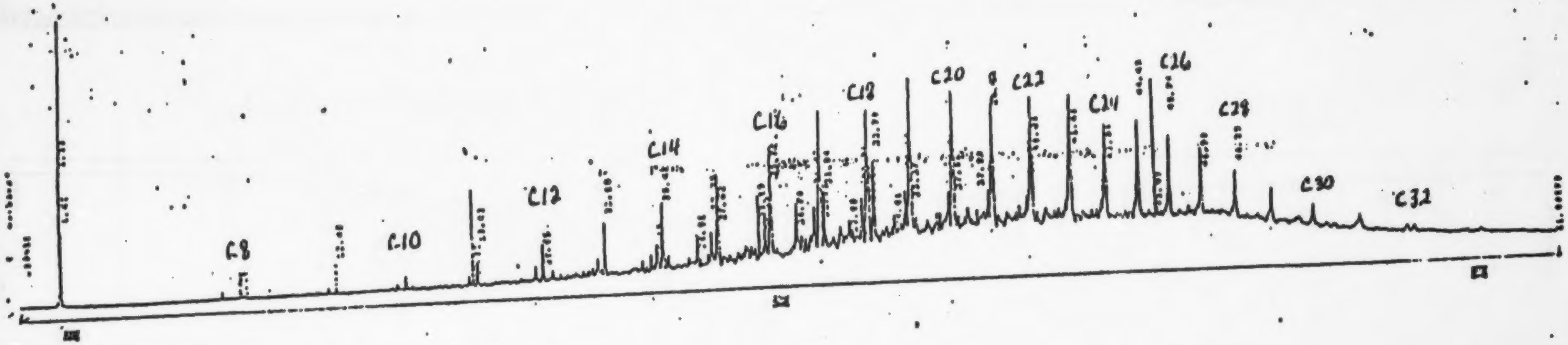


Figure A-7: Chromotogram for Test 3 (Cyclone)

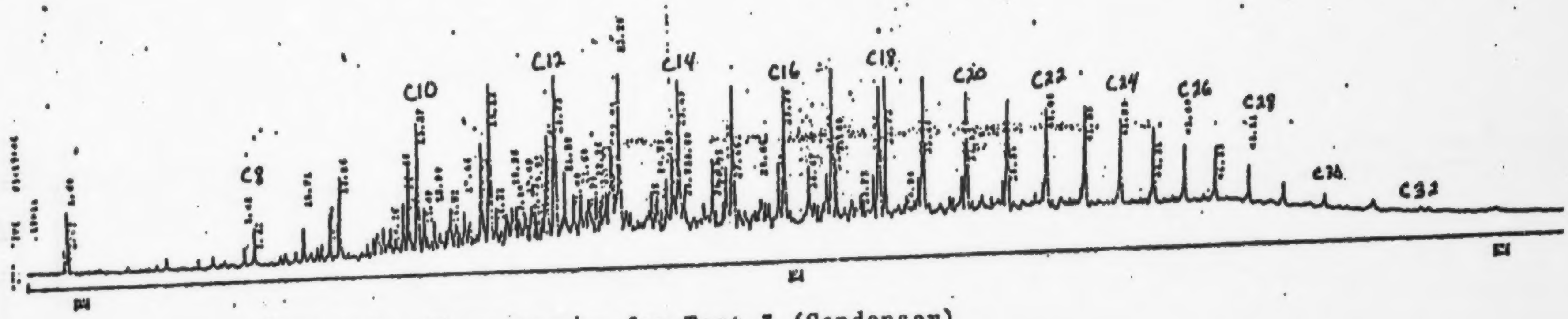


Figure A-8: Chromotogram for Test 3 (Condensor)

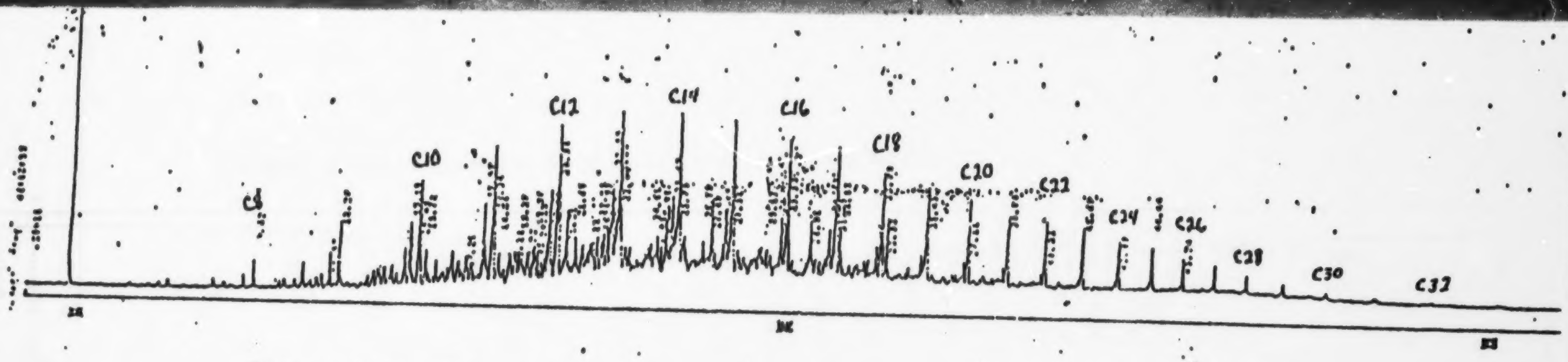


Figure A-9: Chromotogram for Test 3 (ESP)

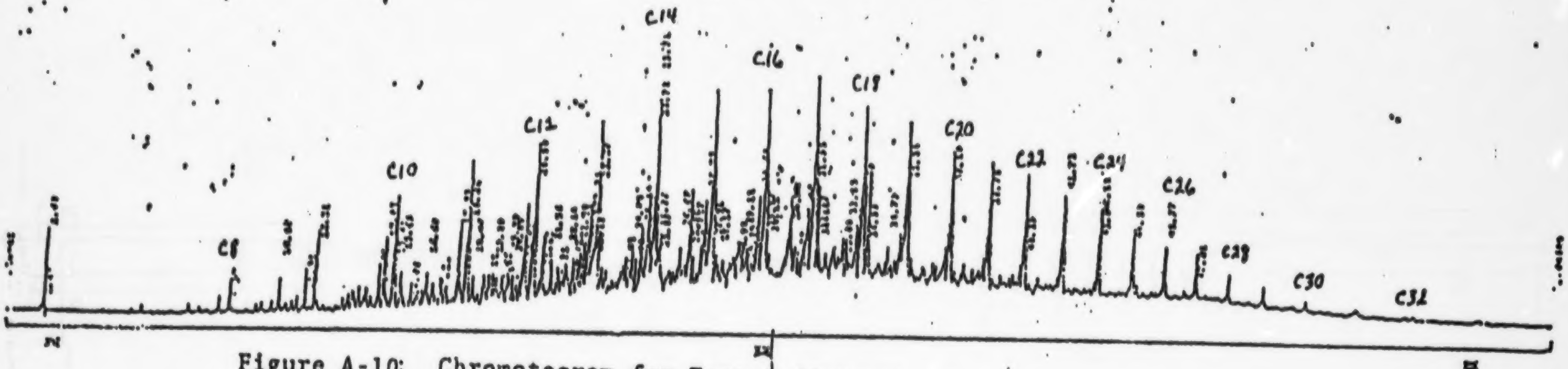


Figure A-10: Chromotogram for Test 3 (Column)

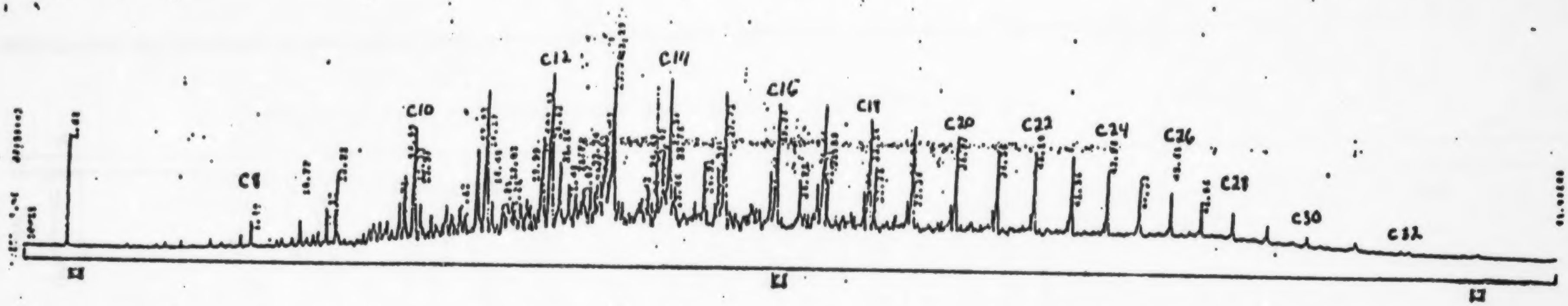


Figure A-11: Chromotogram for Test 4 (Cyclone)

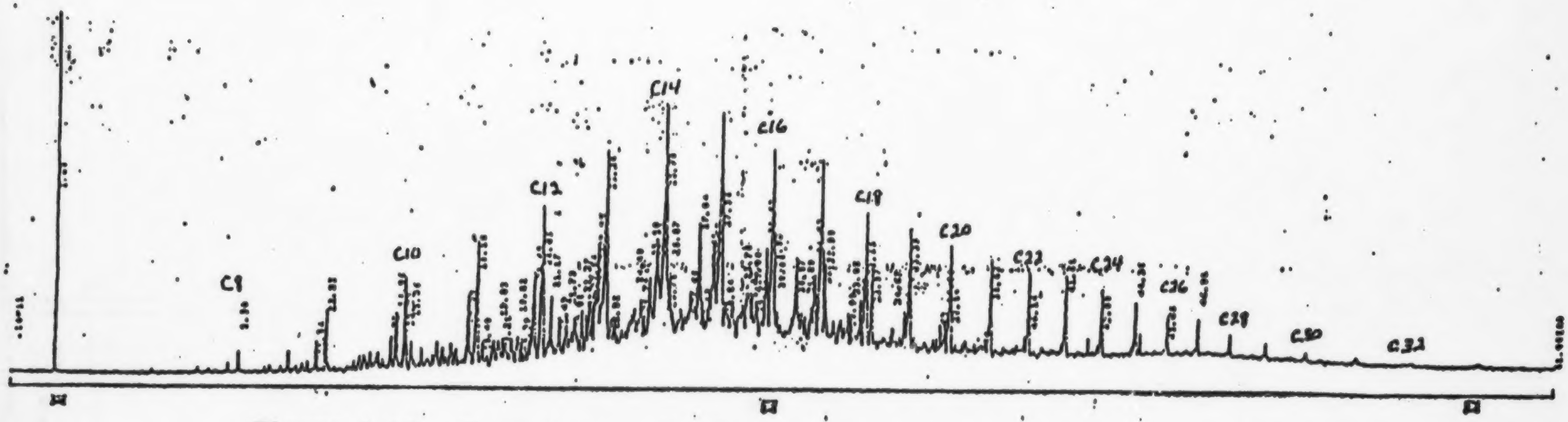


Figure A-12: Chromotogram for Test 4 (Condenser)

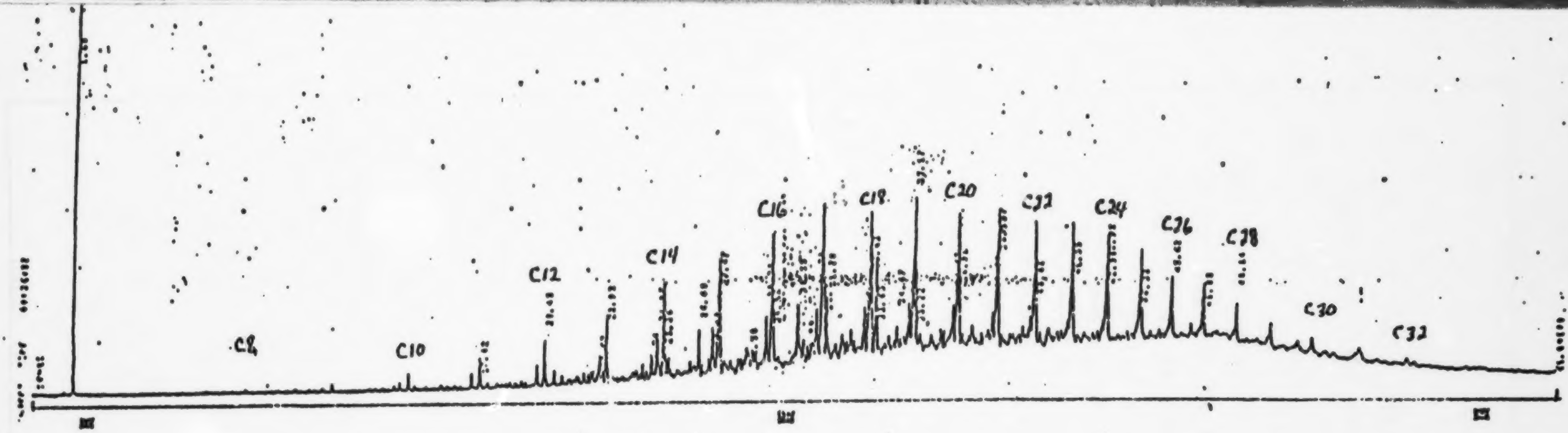


Figure A-13: Chromotogram for Test 4 (ESP)

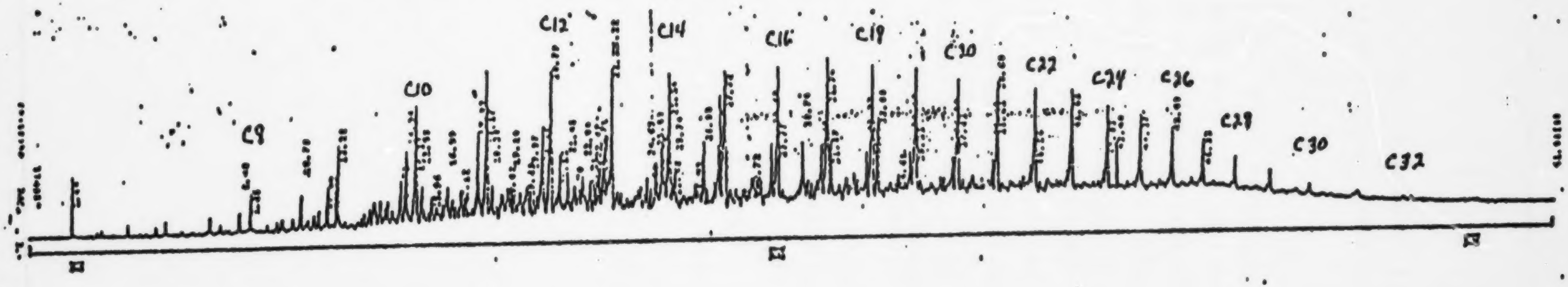


Figure A-14: Chromotogram for Test 4 (Column) and the column in that order. Also, since the table is derived from Figures A-1 to A-14, the figures show the same trend.

Published data (7) for oil products from Green River oil shale using ASTM distilation shows that 60% of the oil boils at temperatures greater than 434°C. Although it is difficult to compare ASTM distillation with the results using chromatography with certainty, according to Table A-1, in excess of 98% of all the oil products have a boiling point below 413°C. This is another indication that New Brunswick shale oil is much lighter than Green River oils.

Gas Analysis

Product gas yields are given in Table 4 and Figure A-15 shows chromatograms of the product gases. The figure shows qualitative gas compositions at various time intervals for runs 2, 3 and 4. In this figure methane represents the major hydrocarbon constituent of the gases.

8d. Chemistry or Characteristics of Albert Shale Oil

J. Synnott and R. Salter, 1983. Modifications of Existing Testing Facilities, Optimization of Hydroretorting Conditions and Assessment of Canadian Oil Shales as Source of Synthetic Fuels. The Research and Productivity Council, Mineral Development and Processing, Report Number MDP/83/12, Page 35.

TABLE 8

COMPOSITION OF SELECTED SHALE OILS FROM HYDROGEN RETORTING TESTS

Samples	Carbon wt %	Hydrogen wt %	Nitrogen wt %	Sulphur wt %	Oxygen wt %	BTU BTU/lb
NB-2a	85.76	11.12	0.70	0.55	1.87	18047
NB-5	85.33	11.06	0.66	0.55	2.40	18497
NB-9	86.62	11.02	0.53	0.50	1.33	18169
NB-11	87.63	10.93	0.73	0.40	0.31	18044
NB-16	85.14	11.21	0.56	0.50	2.59	17677

Section 9

Oil Shale Reserve Estimates

9a. Oil Shale Reserve Estimates

G. Macauley and F.D. Ball, 1982. Oil Shales of the Albert Formation, New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-12, Pages 58-64.

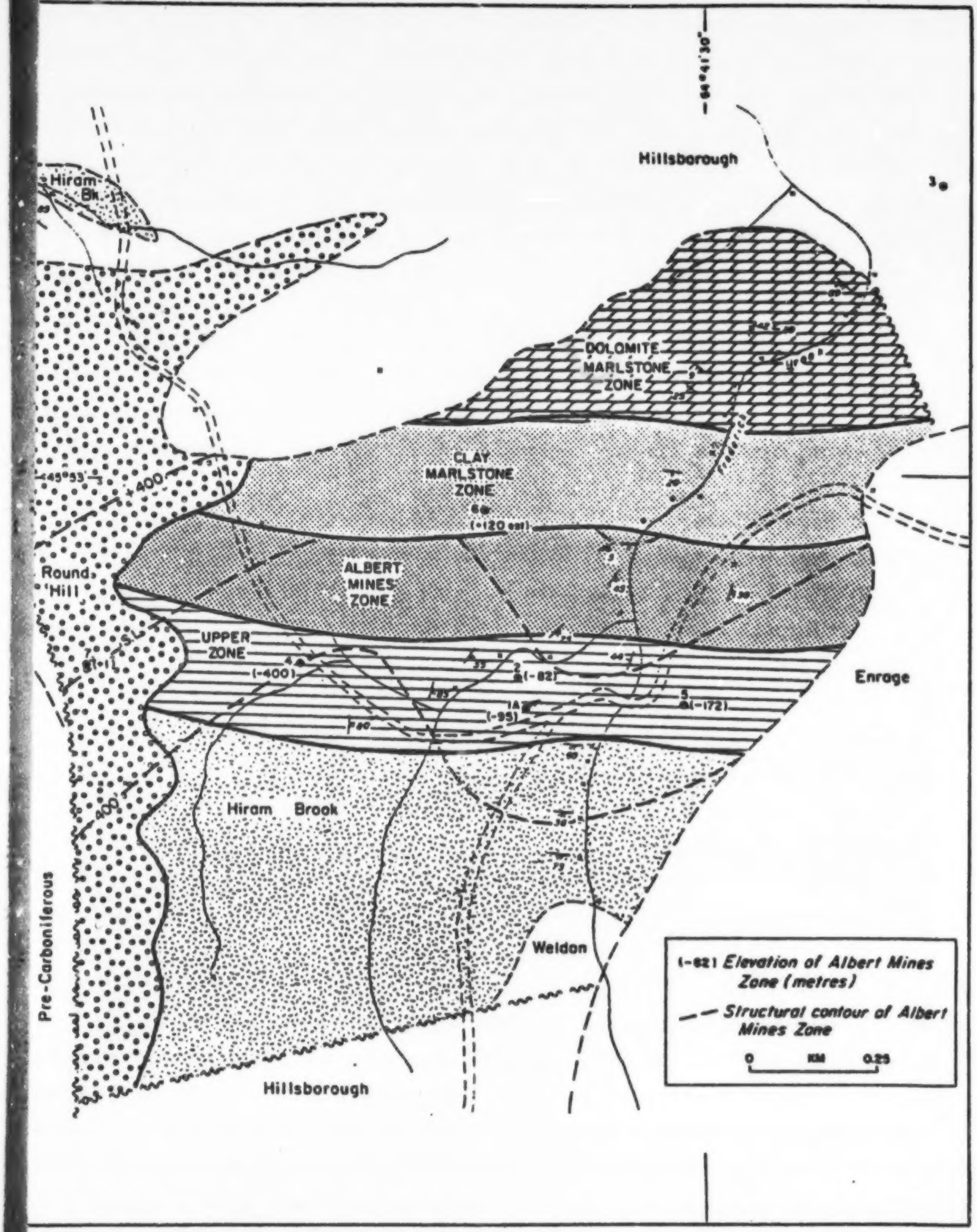
SPECIFIC SITE EVALUATIONS

Albert Mines

The oil shales and albertite vein, cropping out along Frederick Brook approximately 4 kilometres west of the village of Albert Mines in southwestern New Brunswick (Fig. 2), have been the focus of repeated interest since the mid-nineteenth century. Unfortunately, the cores from 36 holes of the Canada Department of Mines program in 1942 have all been discarded; however, the AtlanticRichfield Company (1 hole in 1968) and Canadian Occidental Petroleum Company (7 holes in 1976) cores from eight locations have been retained. Detailed lithologic and geochemical logs from six of these holes (Fig. 4), in conjunction with field notes made by McLeod (1980), are the basis for the geological interpretation of bedrock geology (Fig. 14) and the lithofacies relationships illustrated by cross section (Fig. 15).

The interdigitation of the Round Hill, Hiram Brook, Dawson Settlement and Frederick Brook Members is pronounced adjacent to the Caledonia Uplift, and is particularly evident at the west in Can. Oxy. Albert Mines 7, 4 and 6 (Fig. 4), with the distinction of Hiram Brook and Dawson Settlement Members being one of position relative to the Albert Mines zone (Fig. 3). Across this local area, the Albert Formation becomes finer eastward (Fig. 15) as conglomerate, sand and silt detritus decrease with distance from source. This is economically significant for easterly increasing potential yield and for reduced mining difficulties as the harder coarse clastic facies decreases.

McLeod (1980) placed the Albert Formation at Albert Mines in fault contact with both the pre-Carboniferous rocks of the Caledonia Uplift at the west and the Hillsborough conglomerates


64°41'30"
Hillsborough
Hiram Bk.
3
DOLOMITE MARLSTONE ZONE
CLAY MARLSTONE ZONE
45°53'
400
6
(-120 est)
ALBERT MINES ZONE
Round Hill
SL
7
(-1)
UPPER ZONE
4
(-400)
2
(-82)
1A
(-95)
5
(-172)
Enrage
Hiram Brook
400
Weldon
Pre-Carboniferous
Hillsborough
(-82) Elevation of Albert Mines Zone (metres)
Structural contour of Albert Mines Zone
0 KM 0.25

igure 14: Interpreted surface geology, Albert Mines area, with subsurface contours in the Albert Mines Zone

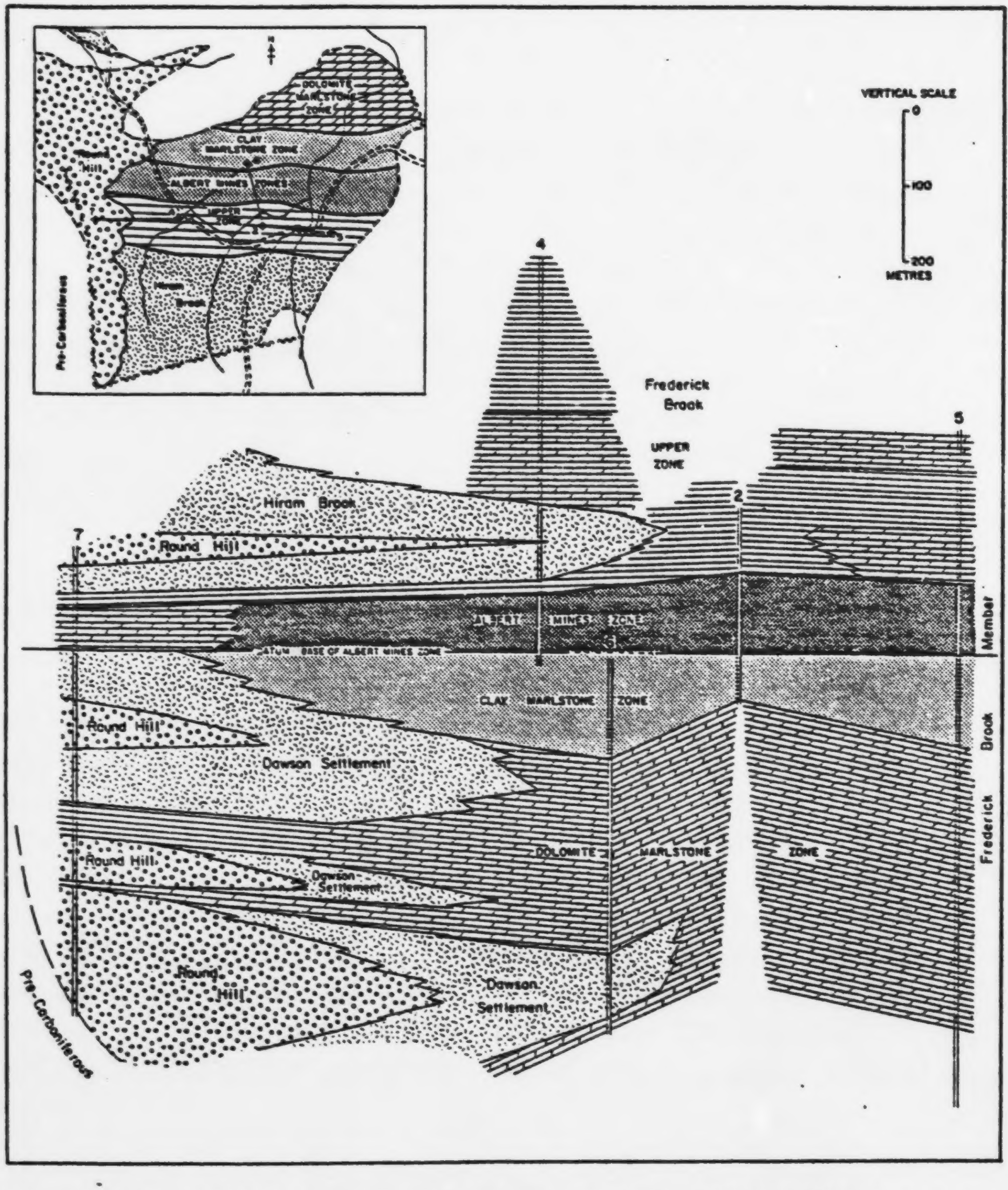

N
DOLOMITE MARLSTONE ZONE
CLAY MARLSTONE ZONE
ALBERT MINES ZONES
UPPER ZONE
Round Hill
Hiram Brook
Pre-Carboniferous
VERTICAL SCALE
0
100
200
METRES
4
Frederick Brook
UPPER ZONE
5
2
7
Hiram Brook
Round Hill
ALBERT MINES ZONE
6
DATUM BASE OF ALBERT MINES ZONE
CLAY MARLSTONE ZONE
Round Hill
Dawson Settlement
Round Hill
Dawson Settlement
DOLOMITE MARLSTONE ZONE
Round Hill
Dawson Settlement
Pre-Carboniferous
Frederick Brook Member

Figure 15: Lithologic correlation section, Albert Mines area

at the south and northeast. The southern contact of the Hiram Brook with the Hillsborough-Weldon (Moncton Group) appears conformable with Hiram Brook-Weldon possibly deposited as facies equivalents. The north-northwesterly relationship of red Hillsborough to grey Round Hill and to other Albert Formation members may be largely a facies change; however, the northeasterly change from lower Albert dolomite marlstone beds to Hillsborough is probably fault controlled.

Pennsylvanian Enrage Formation unconformably overlies Albert beds at the east of the study area: Frederick Brook beds are considered to extend easterly below the Enrage strata, which may extend considerably the area of oil shale potential.

The local structure of the Albert Formation at Albert Mines has been mapped with increasing complexity by successive geologists. Initially the feature was interpreted as a simple southwesterly plunging anticline with the crest along Frederick Brook. Wright (1922) more fully recognized the structural complexity when he mapped the surface and abandoned adits. His graphical reproduction of the underground bedding attitudes (Fig. 16), coupled with those determined from the core (Fig. 4) indicate major structural disruption. Exact locations for the tunnels (Fig. 16), which essentially traverse the Albert Mines zone, are difficult to transfer from older to present map bases. The reader is referred to Wright (1922) or Macauley (1982) for their general locations.

This disruption does not appear to have caused thickened section by repetition, but folding within the higher kerogen zones has structurally expanded the oil shale section. Overturned zones are mapped by Wright and are necessary to explain core dips at AtlanticRichfield Albert Mines 1A.

Because of the folding contortions, the specific surface dips, on which the initial anticlinal interpretation was made, are not considered reliable data on which to base a gross structural analysis. Structure contours on the base of the Albert Mines zone (Fig. 15), as mapped from the core holes, indicate an east-west general strike with a southerly dip at a minimum 55° average. The undulations interpreted on this structural horizon indicate the presence of transverse north-south trending broad anticlinal and synclinal features.

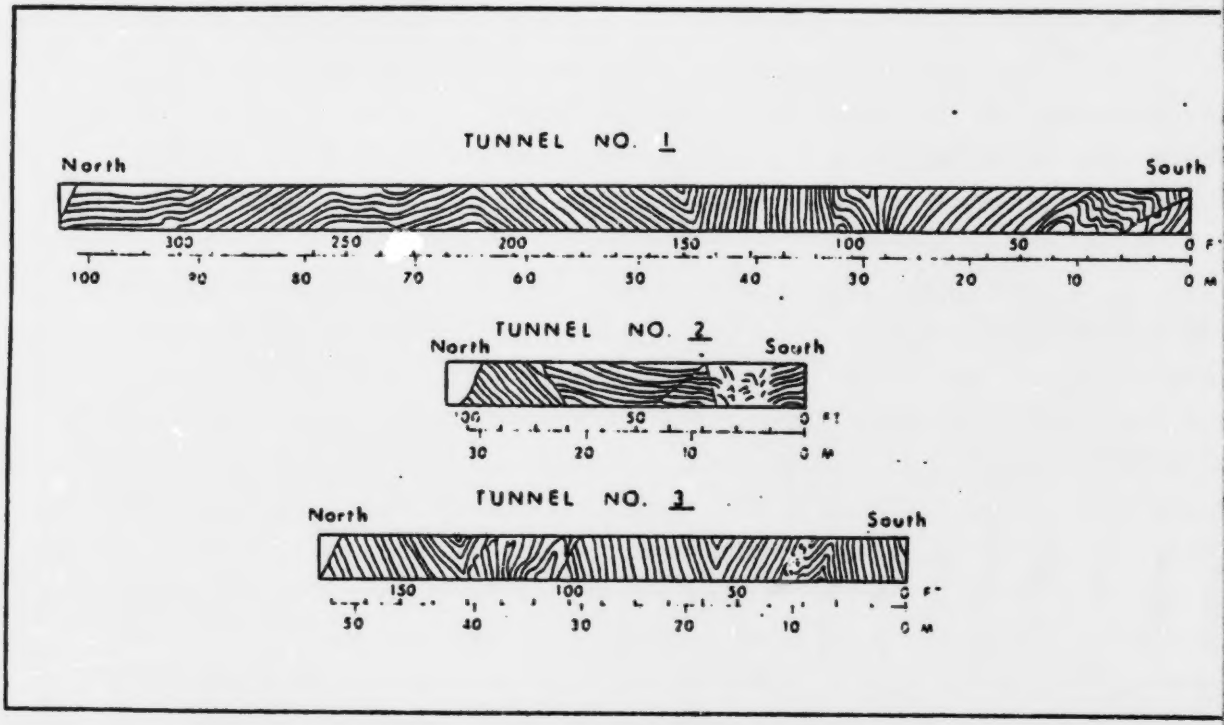

TUNNEL NO. 1
North
South
300
250
200
150
100
50
0 FT
100
90
80
70
60
50
40
30
20
10
0 M
TUNNEL NO. 2
North
South
100
50
0 FT
30
20
10
0 M
TUNNEL NO. 3
North
South
150
100
50
0 FT
50
40
30
20
10
0 M

Figure 16: Structural attitudes of oil shale beds in tunnels at Albert Mines (after Wright, 1922)

Determination of true depositional thickness of the oil shales, particularly of the Albert Mines zone, along with minimum available core hole data, make volume estimates for oil shale reserves nebulous. Based on the dip characteristics encountered in the cores, and better estimates of thickness in the less disturbed Rosevale and Boudreau-Dover areas, 20 metres is possibly conservative and 30 metres not unrealistic as a depositional thickness for the Albert Mines zone. Given the known folding of the zone, the depositional thickness may be expanded to a range of 60 to 100 metres thick across the surface outcrop belt. The degree of folding enhancement may decrease downward as interpreted from thinner Albert Mines zone at the deeper Can. Oxy. Albert Mines 4 core hole. The dolomite marlstone zone is not enlarged by folding and/or faulting.

At the surface, the Albert Mines zone appears to occupy a band approximately 100 metres wide by 1,500 metres east-west. Reducing the estimated width to 60 metres, so that structural deformation essentially doubles depositional thickness, and the length of 1200 metres for possible easterly development of the Round Hill facies in the subsurface, 114.6 x 10^6 tonnes of oil shale are contained to a depth of 600 metres. At an estimated 55° southerly dip, 600 metres drilled depth equates to 730 metres on the zone surface. At an average yield of 93.5 litres/tonne (Table 1), the Albert Mines zone contains estimated in situ shale oil reserves, based on Fischer assay values, of 10.71 x 10^6 cubic metres (67.35 million barrels).

Hole number:	4	6	2	1A	5	Average
Zone:			Yield (litres/tonne)			
Upper			42.5	20.0	43.4	35.3
Albert Mines	80.5		108.8	74.4	110.3	93.5
Clay marlstone	10.3	64.7	33.7	38.6	44.8	38.4
Dolomite marlstone		63.0	60.6	50.5	52.1	56.4

Table 1: Average hydrocarbon yields from the lithologic sub-units of the Frederick Brook Member, Albert Mines area.

Similar calculations for the other sub-units of the Albert Mines area are presented in Table 2: 42.85 x 10^6 cubic metres (270 million barrels) in situ shale oil are estimated for this deposit. These estimates do not include postulated additional oil shale deposits beneath Enrage beds at the east, and make only minor allowance for the influx of Round Hill, Hiram Brook and

Dawson Settlement clastics into the oil shale environment at the west. An indicated easterly improvement in shale oil yields may also be significant to that unexplored area below Enrage beds.

Zone	Thick.	Length	Yield	Density	Mass	In Situ Reserves	
	m	m	l/t	g/cc	$t \cdot 10^6$	$m^3 \cdot 10^6$	$bbls \cdot 10^6$
Upper	75	1000	35.3	2.40	131.4	4.64	29.17
Albert Mines	60	1200	93.5	2.18	114.6	10.71	67.35
Clay marlst.	45	1200	38.4	2.37	93.4	3.59	22.56
Dolomite marlst.	180	1400	56.5	2.30	423.1	23.90	150.35
Total	360				762.5	42.84	269.43

Table 2: Estimated in situ reserves to a depth of 600 metres vertical (730 m on zone surface).

The gravities of the shale oil derived from the Albert Mines area average 0.872 (30.77°, API) and vary only slightly from one zone to the next, with those zones containing greater amounts of clay yielding slightly better quality oil. The average yield versus total organic carbon content of the area is 9.09 litre/tonne per 1% of organic carbon, varying from zone to zone directly with the degree of laminar development. The kerogen, as indicated in Figure 11a and born out by the production index, is very immature, the area having acted as a source for little if any hydrocarbons. No indication of humic content exists based on either the result of sample pyrolyses or core examination. The hydrogen and oxygen indices indicate that the same algal organisms resulted in the kerogen accummulations in each zone which subsequently underwent similar processes of development.

Boudreau

AtlanticRichfield Boudreau 1 (Fig. 5), near Boudreau Village (Fig. 2) on the east side of the Petiticodiac River,

9b. Oil Shale Reserve Estimates

W.B. Timm, F.J. Alcock, A.A. Swinnerton, and S.C. Ells, 1948. Summary of Investigations of New Brunswick Oil Shales. Canada Department of Mines and Resources, Report Number 825, Pages 11-18.

SECTION III

EXPLORATION OF OIL SHALES IN THE ALBERT MINES AREA

(F. J. Alcock)

LOCATION

The Albert Mines oil shale area is in Albert county, about 4 miles southwest of the town of Hillsborough and 20 miles south of Moncton. It is on the Salisbury and Albert branch of the Canadian National Railway, and a good road, branching off from the Hillsborough to Albert highway, traverses it.

AREA AND TOPOGRAPHY

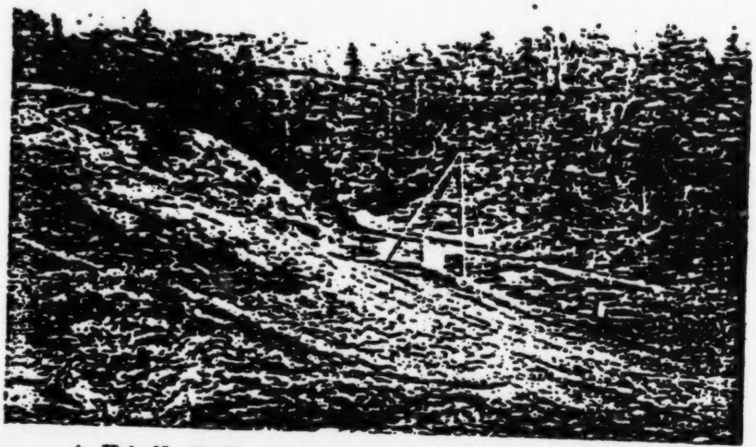
The zone where oil-bearing shales here form the surface rocks has a length in a northeast direction of about one mile and a width in a northwest direction of about three-quarters of a mile. Part of this shale consists of very low-grade material, and part of the area is covered by swamp. The area, as a whole, is a rolling to hilly country traversed in a northeast direction by Frederick Brook, whose valley is steeply entrenched immediately along the brook to a depth of 50 to 80 feet beneath the surrounding flatter country. Most of the region is still wooded.

HISTORY

The region came into prominence in 1849, with the discovery in the bed of Frederick Brook of an outcrop of solid bitumen to which the term Albertite or locally "Albert coal" was given. Between this date and 1880 this material was mined and shipped to the United States, where it was used in the manufacture of illuminating gas. It occurred as a vein cutting across the area in an east-west direction. Later, interest was aroused in the possibilities of the shales of the surrounding region as a source of petroleum. Samples were quoted as running over 40 gallons to the ton, but no systematic work was carried out to definitely determine the average grade. Dr. W. J. Wright, in Memoir 129 "Geology of the Moncton Map-area", published by the Geological Survey in 1922, was the first to point out that the shales vary greatly in their oil content, ranging from rich oil shales to barren shales, and that the assays of a few selected samples did not at all represent the real average value.

WORK OF 1942

Drilling operations to test the area began on July 17, and continued until December 24. The area drilled consists of the part in which the richer shales outcrop and is, roughly, a square with sides 2,400 feet long. Thirty-six holes were put down with lengths varying from 99 to 1,004 feet. The total footage drilled was 13,122 feet. Three holes, Nos. 54, 56,



A. Hole No. 75, Frederick Brook, Albert Mines, New Brunswick.

B. Hole No. 51, Albert Mines, New Brunswick.

and 59. have lengths of 788, 1,004, and 1,000 feet respectively. Aside from these three deeper holes, the average length of the remaining holes is 313 feet.

Twenty-three holes were put down at angles to the vertical in an endeavour to cut the beds as nearly as possible at right angles to the stratification. The remaining thirteen holes were sunk vertically with an average depth from the surface of 312 feet. Neglecting the three deep holes referred to above, the average vertical depth reached by the other thirty-three holes was 269 feet. Eleven holes were put down along Frederick Brook. nine north of the brook, and the remaining sixteen south of the brook. Numbers 40, 43, 44, 45, 46, and 56, north of the brook, are in woods; the remaining holes are in open country. The lowest drilling site, that of No. 54, has an elevation above sea-level of 249 feet. The highest, that of No. 42, south of the brook, has an elevation of 405 feet. The highest drill site north of the brook is that of No. 56, with an elevation of 401 feet.

The cores were assayed in the field, samples being taken from each 5-foot length. The number of core samples run was 2,384. Of this number only sixteen ran over 30 gallons, and only some sixty over 25 gallons to the ton. The highest value was 41·6 gallons for 5 feet from hole No. 38. Table III, pages 14 and 15, summarizes the results.

GEOLOGY

The rocks of the area drilled consist of shales of the Albert formation, which also contains minor amounts of sandstone and a little limestone. The formation is of early Mississippian age. On the west it is in contact with Precambrian volcanic rocks that form a highland. To the north, northeast, and southwest, the shales are overlain by conglomerate of the Moncton group. and to the southeast a conglomerate of Pennsylvanian (Hopewell) age rests unconformably with gentle dips on both the Moncton and Albert beds.

The Albert shales and overlying Moncton beds are thrown into a major anticline whose axis trends along Frederick Brook. As a result, the beds on the northwest side of the brook dip mainly to the northwest and those on the southeast side dip mainly to the southeast. The anticline has a pitch to the southwest upstream. The shales are also greatly deformed by dragfolding and faulting.

The shales vary in colour from grey and bluish grey to brown, brown-grey, and black, and in composition from soft varieties to gritty ones. Some are massive, but bedding planes are usually well marked. The highest oil content is in shales that give a brown streak, and thin-bedded or "paper" shales and minutely contorted or "curly" shales are usually high-grade types. Outcrop samples commonly run higher in oil than those from the same beds that are fresh and unweathered. The reason for this is, apparently, that weathering removes certain constituents, such as lime, leaving behind the bitumen, which accordingly shows as a higher

TABLE III

Summary of Logs

Hole No.	Bearing	Angle from horizontal, degrees	Elevation, feet	Length, feet	Vertical depth, feet	Over-burden, feet	Footage of various grades					Average for entire hole, gallons
							0-5 (gal./ton)	5-10 (gal./ton)	10-15 (gal./ton)	15-20 (gal./ton)	20+ (gal./ton)	
38	S.50° E.	45	352	400	282	33	130	21	55	55	100	12·3
39	N.5° E.	40	323	450	200	35	205	60	50	....	....	4·4
40	S.30° E.	45	370	401	285	32	25	125	124	65	30	11·9
41	N.16° W.	45	308	175	12	25	40	15	40	20	35	12·7
42	N.15° W.	45	405	435	312	32	185	125	40	40	13	7·8
43	S.35° E.	45	309	302	214	50	97	75	45	20	15	8·0
44	S.50° E.	60	321	249	216	21	5	63	110	40	10	11·3
45	S.55° E.	50	341	249	193	102	8	40	79	20	....	11·1
46	N.10° W.	50	323	350	270	35	15	135	135	30	....	10·3
47	N.20° W.	50	341	250	190	26	25	100	85	25	10	11·0
48	N.25° W.	50	340	250	190	28	120	10	25	24	45	9·9
49	N.25° E.	55	300	200	168	27	84	90	10	19	....	7·2
50	E.	50	307	97	75	15	67	5	....	10	....	5·8
51	N.32° E.	55	281	250	206	11	43	84	87	80	47	14·3
52	N.27° E.	60	276	500	435	0	69	158	133	106	32	11·6
53	N.50° E.	80	203	305	300	11	....	131	84	81	18	11·9
54	....	90	219	788	788	21	365	221	120	20	25	7·0

55..........	N.15° E...	45	328	403	283	33	100	85	90	65	30	10·4
56..........	S.45° E....	45	401	1,004	700	17	240	410	250	55	26	9·0
57..........	....	90	328	400	400	25	50	75	95	43	110	14·1
58..........	N.40° E....	43	280	400	332	37	97	79	64	63	60	12·9
59..........	N.15° W...	45	300	1,000	775	27	253	370	225	30	35	9·0
60..........	N.15° W...	45	313	431	300	30	251	110	30	10	....	5·1
71..........	....	90	323	250	250	23	65	80	45	20	13	9·0
72..........	....	90	319	150	150	20	55	30	30	10	5	7·8
73..........	....	90	340	305	305	20	110	40	85	60	80	12·5
74..........	....	90	285	302	302	26	57	120	60	50	40	10·4
75..........	....	90	280	400	400	28	170	170	65	35	25	5·0
76..........	....	90	313	270	270	18	122	95	25	5	5	6·0
77..........	....	90	314	350	350	70	50	90	80	30	30	11·4
78..........	N.10° W...	45	320	251	177	36	93	46	40	10	25	9·2
79..........	N.10° W...	60	320	300	200	21	110	80	30	40	10	8·0
80..........	....	90	300	102	102	53	13	55	30	5	....	8·9
81..........	....	90	357	203	203	23	108	70	40	10	12	3·0
82..........	....	90	301	250	250	30	140	40	35	5	....	5·3
83..........	....	90	204	334	334	19	28	91	79	45	60	13·4

percentage in the weathered rock. Higher grade shale is lighter than low-grade material. Specific gravity tests were run on five core samples with the following results:

	Specific gravity
6·4-gallon shale	2·37
9·1 " "	2·23
11·4 " "	2·22
20·6 " "	1·97
36·5 " "	1·83

It, therefore, takes about 13 cubic feet of average-grade solid material to weigh a ton.

INTERPRETATION OF DRILLING RESULTS

From the point of view of its oil content the Albert shale formation in this area is made up of three main stratigraphic divisions. The upper is a zone whose oil content averages less than 5 gallons to the ton. A grey sandstone 10± feet thick occurs 350± feet stratigraphically above the base of this zone, and is the best horizon marker in the entire formation. Above the sandstone, a thick series of grey shales low in oil grades up into the overlying Moncton beds. A good section of these beds is seen in the creek bed south of hole No. 39. The grey sandstone and the lean beds immediately below it were cut in holes Nos. 39, 56, and 60.

The middle division was cut by the two deep holes, Nos. 56 and 59, and a third section across it is obtained by combining the information from holes Nos. 58, 74, 51, 52, 53, and 54 (*See* longitudinal section along Frederick Brook, Figure 4). This zone has a stratigraphic thickness of 700± feet. Its average oil content, as obtained by averaging the results of all the wells that intersect or partly intersect it, is 10·6 gallons. Below this zone, the third division consists of bluish grey shales with an average oil content, where cut by the three deep holes, of less than 5 gallons to the ton. It is possible that, below the zone explored by drilling, beds running more than this figure may occur.

As a result of the anticlinal structure referred to in the section on geology, and of the erosion which has removed the crest of the fold, the beds of the richer middle zone are brought to the surface along Frederick Brook. The surface width of this exposed belt in a northwest direction averages 1,600 feet. The eastern border is a north-south fault between holes Nos. 59 and 60, to the east of which the lower grade shales and sandstone of the upper zone have been dropped down so that they then form the surface rocks. The western limit is near hole No. 39, where, owing to the western pitch of the anticline, the upper lean zone here also forms the surface beds. The exposed length of the middle zone is, therefore, around 2,400 feet. The vertical depth averages at least 400 feet. There is available, therefore, on the basis of 15 cubic feet to the ton approximately 100,000,000 tons of 10·6-gallon shale above the 400-foot level. This would be available by open-cut mining, assuming vertical walls, and more could be obtained by following the zone down by underground mining beneath the lean beds on the flanks of the anticline. The overburden would probably average around 10·6 gallons also. The amount of drift in most places is slight, the surface material consisting largely of broken and weathered shale.

Part of the middle zone referred to above runs considerably above the 10·6-gallon average, but, when an attempt is made to compute tonnages of higher grade material available, difficulties, for a number of reasons, arise.

(1) The same beds vary in their oil content both along the strike and down the dip.

(2) In many of the holes the drill cut the beds at low angles to the bedding, in places ran for considerable distances parallel to the stratification, and certain sections of core showed that the dips became reversed. Core lengths of high-grade material in such cases do not mean similar real thicknesses of such high-grade value. It may merely mean a thin rich zone followed by the drill at a low angle or repeated by folding.

(3) The lack of definite horizon markers in the middle oil-shale zone makes it impossible to definitely correlate beds, to work out details of structure, and hence calculate tonnages with confidence.

Two methods of calculation to determine tonnages of richer material may be employed, both of which have their advantages and their disadvantages. One may endeavour to use stratigraphic zones, or, secondly, one can disregard stratigraphy and structure entirely and use the drilling results to determine mass averages. The former of these methods allows a more accurate estimate to be made of the average oil content of the beds, and gives also some idea as to what may be expected beyond the bounds of the territory actually blocked out by the drilling. The latter method affords definite information on the tonnage blocked out, but without very closely spaced drilling, calculated averages, for the reasons already pointed out, may be far from actual averages. An attempt is, therefore, made below to use the stratigraphic method to estimate the amount of higher grade material.

A restricted area surrounding hole No. 51 shows considerable thickness of 20+ gallon shale and a number of holes more closely spaced than those in the rest of the area were put down to explore this belt. Although, as stated above, horizon markers are lacking, and beds vary in their oil content both along the strike and the dip, nevertheless it is reasonable to assume that in a limited area, a few hundred feet across, the high-grade beds cut in the various holes probably represent the same stratigraphic zone. From the angle of bedding to core axis, an attempt has been made to infer the stratigraphic thickness represented in the following holes:

Hole No.	Footage of richer beds	Core length, feet	Probable stratigraphic thickness, feet	Average oil content, gallons
38	33—250	217	90 ±	20·1
51	86—181	95	80 ±	20·8
52	0— 45	45	45 ± (top missing)	22·6
58	150—300	150	100 ±	20·3
73	145—275	130	80 ±	19·2
74	185—290	105	60 ±	17·0
75	335—395	60	35 ±	18·0
Average	....	....	70 ±	19·7

The length of this zone in a southwest direction from where it comes to the surface at hole No. 52 to beneath No. 58 is 600 feet. No matter what the structure is, it is probable that the dimension normal to this is at least 600 feet also. This would make a tonnage of $\frac{600 \times 600 \times 70}{15}$ or 1,680,000 tons of 19·7-gallon material. In addition, along the south limb of the anticline, 40-foot widths of 20+ gallon material were cut in holes Nos. 41, 42, 48, and 59. Assuming this to be a belt with a strike length of 1,000 feet and that it maintains its value down the dip for a distance of 250 feet, there would be an additional tonnage of $\frac{1,000 \times 250 \times 40}{15}$ or 666,000 tons of 20-gallon material. On the north flank of the anticline the zones of such material are too thin and discontinuous to be considered separately. The probable tonnage of material averaging 20 gallons that might be expected to be recoverable is, therefore, around 2,350,000 tons and most of this would have to be secured by selective mining. To take out any considerable proportion of this by open-cut methods would involve excavating lower grade material that, it is estimated, would reduce the average grade to about 12 to 14 gallons.

The second method referred to above, that of using the drilling assays to determine mass averages, has been employed by Dr. H. M. A. Rice of the Geological Survey, by use of a model of the area to work out tonnages of several grades. The writer has checked his figures and believes that his is as fair an estimate as can be made by this method from the data available. Dr. Rice concludes that there is a probable tonnage, of 2,111,100 tons of 18-gallon material, and 3,043,700 tons of 15-gallon material, the latter including the former. The blocked-out area will possibly supply 22,363,700 tons of material that will average 12 gallons to the ton, including the richer material referred to above.

In summary, the writer is of the opinion that if a large tonnage of material capable of being mined by open-cut methods is required, one must be prepared to treat shales of from 10- to 12-gallon grade. Richer material of around 20 gallons to the ton is present in an amount of the order of magnitude of 2,000,000 tons. Most of this would have to be secured by selective mining if it were necessary to maintain this grade. Some 20,000,000 tons of 12-gallon material could be obtained by open-cut methods, and a block with vertical walls contains 100,000,000 tons of 10·6-gallon material.

9c. Oil Shale Reserve Estimates

J.K. Worth, 1977. Oil Shale and Lithofacies, Albert Formation, Hillsborough Sub-Basin, New Brunswick. In Report for Canadian Occidental Petroleum Ltd., Calgary, Alberta, Appended Letter.

FUNDY GEOSERVICES LTD.
Mineral Resource Consultants and Contractors

SAINT JOHN, NEW BRUNSWICK, CANADA

CANADIAN OCCIDENTAL PETROLEUM LTD.
CALGARY, ALBERTA

RE: SHALE OIL RESERVES IN THE ALBERT MINES AREA, NEW BRUNSWICK.

Drilling results from the 1976 oil shale programme were combined with results from previous programmes to estimate the shale oil reserves of the Albert formation in the Albert Mines area. A rough, conservative estimate of 165.24 million barrels of shale oil was obtained. These "in situ" reserves underlie an area of about 1 square mile, are within a stratigraphic interval of 889', and lie within 2000' of the surface. The oil shale succession forms part of the Frederick Brook Anticline and dips from 50° to 70° along the flanks of this structure.

Five bituminous shale zones were recognized in the Albert Mines area. Three of these average over 10.0 US gallons/ton and were used to arrive at the 165 million barrel estimate. In descending stratigraphic order, these are:

(1) The Gesner Zone, of undetermined stratigraphic thickness containing less than 10 gpt;

(2) The Victoria Zone, averaging 158' and containing an average of 23.4 gpt;

(3) The Albert Zone, averaging 421' and containing an average of 12.1 gpt;

(4) The East Zone, averaging 310' and containing an average of 11.1 gpt;

and (5) The basal zone of undetermined stratigraphic thickness containing an average of less than 5 gpt.

The logs of Can Oxy Albert Mines #5 (T.D. 2857') are enclosed as a type intersection of these zones.

Structural contour and isopach maps were constructed from Can Oxy, ARCO, and Government of Canada drilling records. Due to the lack of any lithologic descriptions of the government-sponsored drilling and the lack of assay data on the ARCO cores, the contouring results are far from satisfactory. (See Structural Contour - Isopach and Profile Plates).

The structural geology of the Albert Mines area is dominated by the Frederick Brook Anticline. The configuration of this structure is somewhat concealed due to minor tectonic folding, minor faulting, and folding due to soft sediment slumping of the strata. In addition, the base of the Victoria Zone was recognized as an unconformity thereby accounting for the erratic thickness variations of the underlying Albert Zone which preclude the construction of isopachs on that zone. No major faults were recognized within the area analysed in this report. (See Geological Compilation Plate).

Some measure of confidence can, however, be placed in the subsurface maps, therefore rock tonnage estimates were computed for the Victoria, Albert and East Zones. The results were used to obtain a very conservative estimate of the quantity of shale oil in each of the three higher-yielding zones to a depth of 2000' as follows:

Victoria Zone: 82.89 million short tons averaging 23.4 US gpt	46.18 million bbl.
Albert Zone: 246.19 million short tons averaging 12.1 US gpt	70.93 million bbl.
East Zone: 182.13 million short tons averaging 11.1 US gpt	48.13 million bbl.
TOTAL	165.24 million bbl.

Further drilling could be undertaken to prove this 165 million barrel estimate or to extend these reserves to the north of the area shown on the accompanying Plates. Drilling in the eastern part of the area is not recommended; if the interpretation given on Profile C-D is correct, very low grade shale from the basal zone will be intersected.

Respectfully,
FUNDY GEOSERVICES LTD.

J.K. Worth, Geologist
Jan 25/77

Section 10

Summary Geology of the Albert Formation

10a. Summary Geology of the Albert Formation

C. St. Peter, 1982. Geology of the Albert Formation, New Brunswick, Canada. In Proceedings, 1982 Eastern Oil Shale Symposium, University of Kentucky, Institute for Mining and Minerals Research, Pages 39-47.

Geology of the Albert Formation, New Brunswick, Canada

by

C. St. Peter
Geologist
New Brunswick Department for Natural Resources
Mineral Development Branch, P. O. Box 6000
Fredericton, New Brunswick, E3B 5H1

Abstract. The Albert Formation lies near the base of a thick Upper Devonian to Upper Carboniferous sequence of predominantly continental rocks within the Moncton Subbasin of southeastern New Brunswick. The Moncton Subbasin constitutes a graben within the regional Fundy Basin which developed from block faulting of a Precambrain and Lower Paleozoic basement complex in Late Devonian time.

The Albert Formation comprises a 200 to 2000 m thick sequence of grey alluvial fan, fluviatile, deltaic, evaporitic and lacustrine facies that is underlain and overlain by alluvial fan and fluviatile redbeds. The lacustrine oil shale facies is best developed in the southeastern part of the Subbasin where it comprises abundant massive and laminated, kerogen-bearing, dolomitic strata. The preservation of delicate laminations, and the presence of accessory analcime, and fresh water fish attest to quiescent alkaline, lacustrine deposition.

The oil shale facies shows evidence of soft sediment folding. The entire Albert Formation is openly folded. The Formation is transected by several regional faults that greatly complicate stratigraphic reconstruction.

Introduction

The Albert oil shales in the Moncton Subbasin of southeastern New Brunswick are by far the most widely known rocks in the Province. The oil shales have been investigated for well over one hundred years. The Formation contains the Stoney Creek Oilfield, the only producing oil and gas reservoir in eastern Canada.

This study records the preliminary results of a regional facies and tectonic examination of the Albert Formation. The Formation is seen to consist of five major facies - alluvial fan, fluvial, deltaic, evaporitic and lacustrine.

The Albert rocks are more pervasively deformed than previously believed. The lacustrine oil shales are highly tectonized in the southeastern part of the Moncton Subbasin.

1982 EASTERN OIL SHALE SYMPOSIUM • Kentucky Department of Energy and the University of Kentucky Institute for Mining and Minerals Research Lexington, Kentucky, 40512 • October 11-13, 1982

Fundy Basin and Moncton Subbasin

Following the compressional climax of the Acadian Orogeny in Middle Devonian to early Late Devonian time the Precambrian to lower Paleozoic basement underwent an extensional block-faulting phase giving rise to a regional downwasp - the Fundy Basin. The Fundy Basin extends from southeastern New Brunswick eastwards across northeastern Nova Scotia, through Cape Breton Island to western Newfoundland (Figure 1).

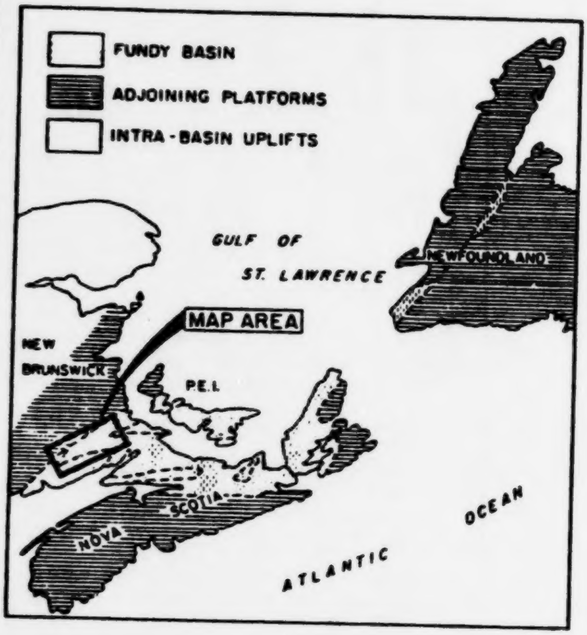


Figure 1. Major tectonic elements of Fundy Basin

The Fundy Basin is a complex structure comprising numerous horsts (uplifts) and grabens (subbasins). One of the grabens, the Moncton Subbasin, lies in southeastern New Brunswick. It is a wedge-shaped structure about 130 miles (200 km) in length and it opens to the northeast (Figure 2). The Subbasin is in contact with the New Brunswick Platform on the northwest along the Belleisle Fault. The southern margin of the Subbasin is defined by the Dorchester Fault and the basement rocks of the Caledonia Uplift. The eastern end of the Subbasin is bifurcated by the Westmorland Uplift which is largely covered by Upper Carboniferous strata.

Stratigraphy in the Moncton Subbasin

The Moncton Subbasin is largely infilled by a thick sequence of Upper Devonian to Upper Carboniferous terrestrial strata that display complex facies interrelationships. During Early Carboniferous Viséan time, the terrestrial deposits were transgressed by the Windsor sea providing the only time marker within the Subbasin[1].

The Memramcook Formation defines the base of the basin fill succession. It lies with angular unconformity on the basement complex and largely consists of red alluvial fan conglomerate, conglomeratic sandstone and mudstone near the Caledonia Uplift in the south and near the Belleisle and Jordon Mountain Faults in the north (Figure 2). Clasts within the conglomerates clearly show that the adjoining basement complex provided the detritus for the Memramcook Formation. On the south flank of the Westmorland Uplift the Memramcook Formation comprises fining upward sequences of fluvial grey cross-bedded sandstone, and red shale. Spores from these rocks indicate a Late Devonian to Early Carboniferous (Tournaisian) age[2].

The Memramcook Formation is conformably overlain by the Albert Formation; the latter is exposed along the southern, western and northern margins of the Moncton Subbasin. The Albert comprises an array of rock types assignable to five major facies - alluvial fan, fluvial, deltaic, lacustrine, and evaporitic. A more detailed description of the facies is given below under Albert Formation Facies.

The Albert Formation shows a considerable range in thickness and appears to be thickest in the central part of the Subbasin. At Walker Brook, 15 km (10 miles) southeast of Sussex, the Formation is 200 m (650 feet) in thickness. In the southern axial part of the Subbasin the Albert is greater than 1500 m (4800 feet) in thickness[3]. Northwest of the Jordon Mountain Fault along the northwestern side of the Subbasin the Albert is about 950 m (3000 feet) thick and in the southeast, east of the Stoney Creek Oilfields, the Formation is estimated to be 1400 m (4500 feet) thick. Elsewhere, the Albert is incompletely exposed as a result of faults or it is unconformably covered by younger strata.

The Albert Formation has recently been dated by palynomorphs from the southwestern[3] and southeastern[4] parts of the Subbasin as ranging from Late Devonian (Famennian) to Early Carboniferous (Tournaisian).

The Albert Formation is conformably overlain by the Moncton Group comprising two formations. The lower Weldon Formation is represented by fluvial red sandstone and mudstone in some places and by debris flow conglomerate and mudstone in others. The Hillsborough Formation is mostly coarse-grained red muddy debris flow conglomerate and sandy sheet flood conglomerate. Along the southern margin

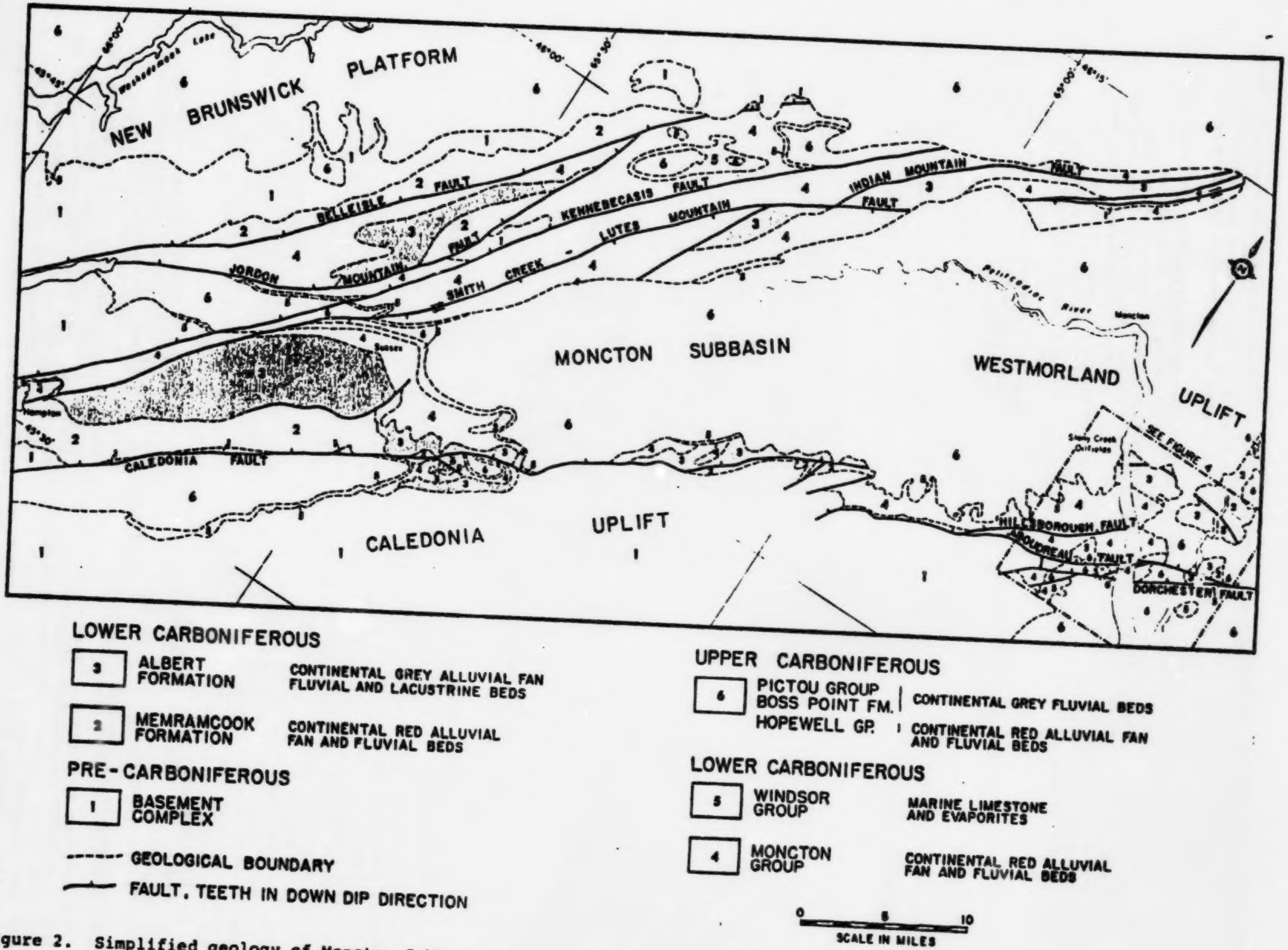

NEW BRUNSWICK PLATFORM
MONCTON SUBBASIN
WESTMORLAND UPLIFT
CALEDONIA UPLIFT
BELLEISLE FAULT
JORDON MOUNTAIN FAULT
KENNEBECASIS FAULT
SMITH CREEK - LUTES MOUNTAIN FAULT
INDIAN MOUNTAIN FAULT
CALEDONIA FAULT
HILLSBOROUGH FAULT
ABOUDREAU FAULT
DORCHESTER FAULT
SEE FIGURE 4
Petitcodiac River
Moncton
Sussex
Hampton
Stony Creek Oilfields
LOWER CARBONIFEROUS
3 ALBERT FORMATION CONTINENTAL GREY ALLUVIAL FAN FLUVIAL AND LACUSTRINE BEDS
2 MEMRAMCOOK FORMATION CONTINENTAL RED ALLUVIAL FAN AND FLUVIAL BEDS
PRE-CARBONIFEROUS
1 BASEMENT COMPLEX
GEOLOGICAL BOUNDARY
FAULT, TEETH IN DOWN DIP DIRECTION
UPPER CARBONIFEROUS
6 PICTOU GROUP BOSS POINT FM. CONTINENTAL GREY FLUVIAL BEDS
HOPEWELL GP. CONTINENTAL RED ALLUVIAL FAN AND FLUVIAL BEDS
LOWER CARBONIFEROUS
5 WINDSOR GROUP MARINE LIMESTONE AND EVAPORITES
4 MONCTON GROUP CONTINENTAL RED ALLUVIAL FAN AND FLUVIAL BEDS
0 5 10
SCALE IN MILES

Figure 2. Simplified geology of Moncton Subbasin

of the Subbasin the Hillsborough Formation unconformably overlies the Weldon Formation[5]. It has been reported that the rocks lying below the Hillsborough unconformity have undergone a folding event not evident in the overlying strata[3,4].

The Moncton Group is disconformably to conformably overlain by the Lower Carboniferous (Viséan) Windsor Group. The Windsor comprises three basal limestone formations, an overlying anhydrite-gypsum sequence, and economically important potash beds[1]. The Windsor is a time line and the only reliable stratigraphic marker in the Moncton Subbasin.

The Windsor Group is conformably to unconformably overlain by Upper Carboniferous strata that are divided into three major continental sequences. In ascending order, they are: the Hopewell Group, the Boss Point Formation and the Pictou Group. The Hopewell Group is largely composed of alluvial fan redbeds with lesser red fluviatile beds. The Boss Point and Pictou rocks are mostly grey meandering stream deposits. The Upper Carboniferous strata is widespread in the central part of the Subbasin and conceal all the lower Carboniferous formations.

Albert Formation Facies

The Albert Formation comprises five major facies - alluvial fan, fluvial, deltaic, evaporitic and lacustrine (Figure 3).

The alluvial fan facies occurs only along the southern edge of the Subbasin adjacent to the Caledonia Uplift. The facies includes interbedded pebble to boulder conglomerate, pebbly sandstone and mudstone. Along the eastern end of the Uplift the coarse-grained rocks contain interbeds of dolomitic, kerogenous shale similar to those of the lacustrine facies (described below). The conglomerate and sandstone beds are up to several metres thick and are typical debris flow and sheet flood deposits[6]. Clasts within the conglomerates are angular to subangular, poorly sorted and are easily matched with basement lithotypes to the immediate south.

The fluvial facies is more widespread than the alluvial fan rocks. Fluvial strata comprise the entire belt northwest of the Jordan Mountain Fault. Fluvial rocks overlie lacustrine rocks in the northeastern part of the Subbasin at Indian Mountain. Most of the undivided sequence of fluvial and deltaic rocks in the southwestern part of the Subbasin from Hampton to Sussex are fluviatile.

The fluvial facies is defined by fining upward sequences of conglomerate, cross-bedded and ripple-laminated sandstone, and minor siltstone and shale. The conglomerate occurs in beds 0.5 to 5 m (1.5 to 15 feet) in thickness that are comprised of rounded competent pebbles and cobbles in a quartzose or feldspathic arenite matrix. The interbeds of sandstone range from 5 cm to 10 m (2 inches to 30 feet) in thickness and are typically cross-bedded to flaggy with the upper parts of the beds displaying ripple laminations.

The sandstone beds in places contain abundant plant fragments. Many of these have been identified, among them are: *Alethopteris heterophylla*, *Aneimites acadica*, *Cyclopteris acadica*, *Dadxylon antiquius*, *Lepidodendron corrugatum*, *Micheevia corrugata*, and *Telangium* sp.[5,7,8].

Siltstone and shale are commonly interbedded with the coarser grained rocks. They in places display mudcracks and nodules of carbonate and gypsum. The siltstone and shale beds apparently represent vertical accretion overbank deposits.

Cross beds and ripple laminations in the sandstones indicate a northeasterly transportation direction for the fluvial detritus in the belt northwest of the Jordon Mountain Fault (Figure 3). Similar northeasterly dispersal directions have been determined for the sediments in the Hampton to Sussex belt[9]. The fluvial strata in the northeastern part of the Subbasin at Indian Mountain show an opposing transportation direction towards the southwest.

Deltaic rocks are exposed southwest of Indian Mountain along North River. Deltaic strata are associated with lacustrine rocks in the southeastern part of the Subbasin (Figure 4). Similar deltaic rocks have been described from the Hampton-Sussex belt to the southwest[9].

In the North River belt the rocks are interbedded grey siltstone and claystone with minor thin beds of grey, medium- to fine-grained, current-laminated and graded sandstone. The rocks are in places calcareous and contain thin beds of fine-grained muddy limestone. Small plant fragments are abundant along sandstone-siltstone contacts. The siltstone and claystone commonly display mudcracks and diagenetic carbonate nodules. Current ripples from the sandstone beds give consistent southwesterly directed transport (Figure 3). The sandstone beds are believed to have resulted from a waning current; the siltstones and claystones apparently formed from suspension load deposition. The beds are interpreted to be delta topset deposits.

The deltaic rocks in the southeastern part of the Subbasin are largely similar to those along North River. However, in the southeast, in addition to fine-grained sandstone, siltstone and claystone, there are also thick interbeds of grey,

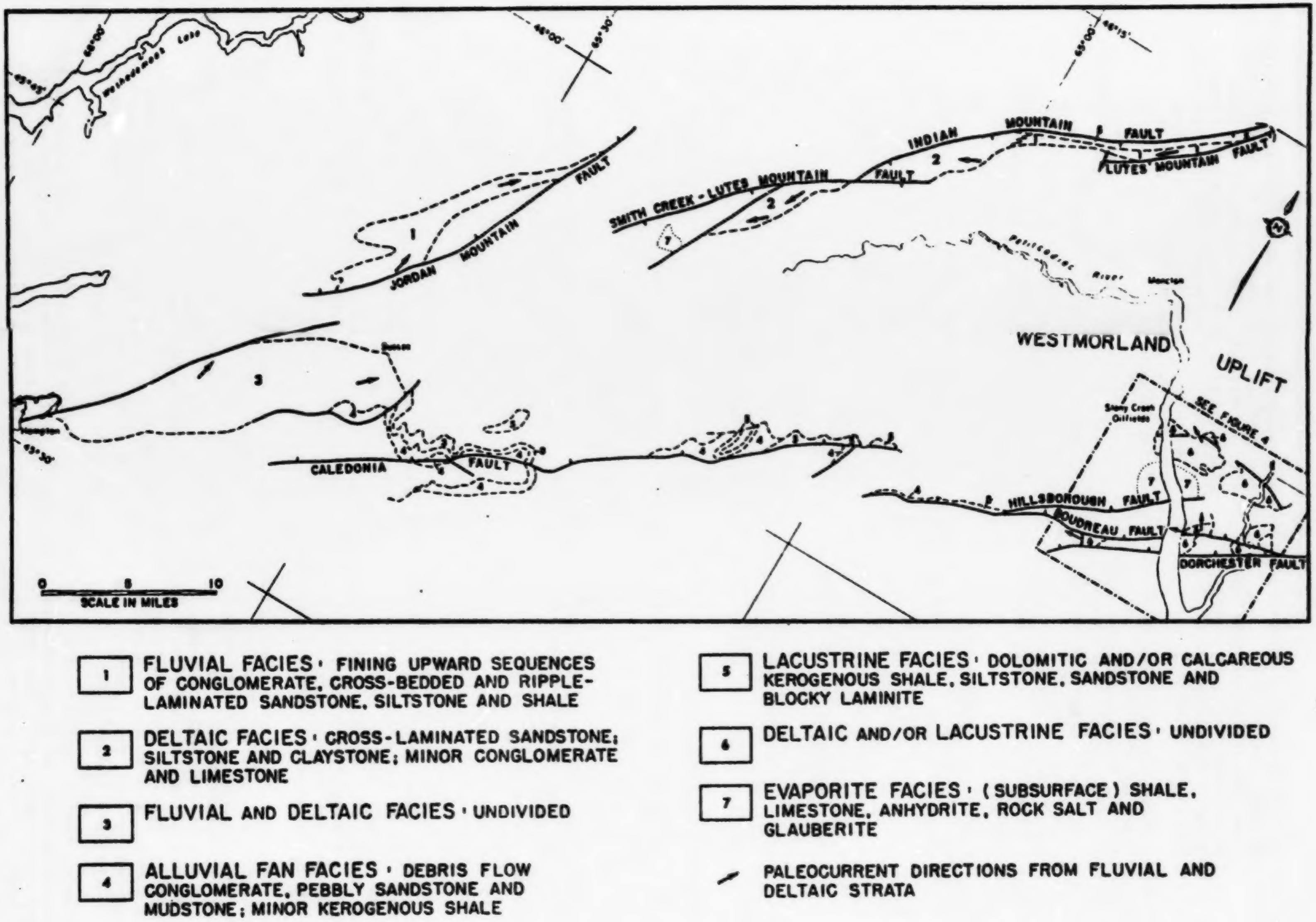

JORDAN MOUNTAIN FAULT
SMITH CREEK - LUTES MOUNTAIN FAULT
INDIAN MOUNTAIN FAULT
LUTES MOUNTAIN FAULT
Petitcodiac River
Moncton
WESTMORLAND UPLIFT
SEE FIGURE 4
Stony Creek Oilfields
CALEDONIA FAULT
HILLSBOROUGH FAULT
BOUDREAU FAULT
DORCHESTER FAULT
Washademoak Lake
Sussex
Hampton
0 5 10
SCALE IN MILES
1 FLUVIAL FACIES · FINING UPWARD SEQUENCES OF CONGLOMERATE, CROSS-BEDDED AND RIPPLE-LAMINATED SANDSTONE, SILTSTONE AND SHALE
2 DELTAIC FACIES · CROSS-LAMINATED SANDSTONE; SILTSTONE AND CLAYSTONE; MINOR CONGLOMERATE AND LIMESTONE
3 FLUVIAL AND DELTAIC FACIES · UNDIVIDED
4 ALLUVIAL FAN FACIES · DEBRIS FLOW CONGLOMERATE, PEBBLY SANDSTONE AND MUDSTONE; MINOR KEROGENOUS SHALE
5 LACUSTRINE FACIES · DOLOMITIC AND/OR CALCAREOUS KEROGENOUS SHALE, SILTSTONE, SANDSTONE AND BLOCKY LAMINITE
6 DELTAIC AND/OR LACUSTRINE FACIES · UNDIVIDED
7 EVAPORITE FACIES · (SUBSURFACE) SHALE, LIMESTONE, ANHYDRITE, ROCK SALT AND GLAUBERITE
PALEOCURRENT DIRECTIONS FROM FLUVIAL AND DELTAIC STRATA

Figure 3. Albert Formation facies, Moncton Subbasin

coarse- to medium-grained, highly micaceous quartzose sandstone. The sandstone along Petitcodiac River (Figure 4) displays alternating sequences of parallel laminations and ripple cross laminations in beds up to 6 m (20 feet) in thickness. In the Stoney Creek Oilfield on the west side of the Petitcodiac River the sandstone strata with minor associated conglomerate form layers up to 35 m (110 feet) in thickness[10]. Paleocurrent analyses from the ripple-laminated sandstones show a west to northwest transportation direction.

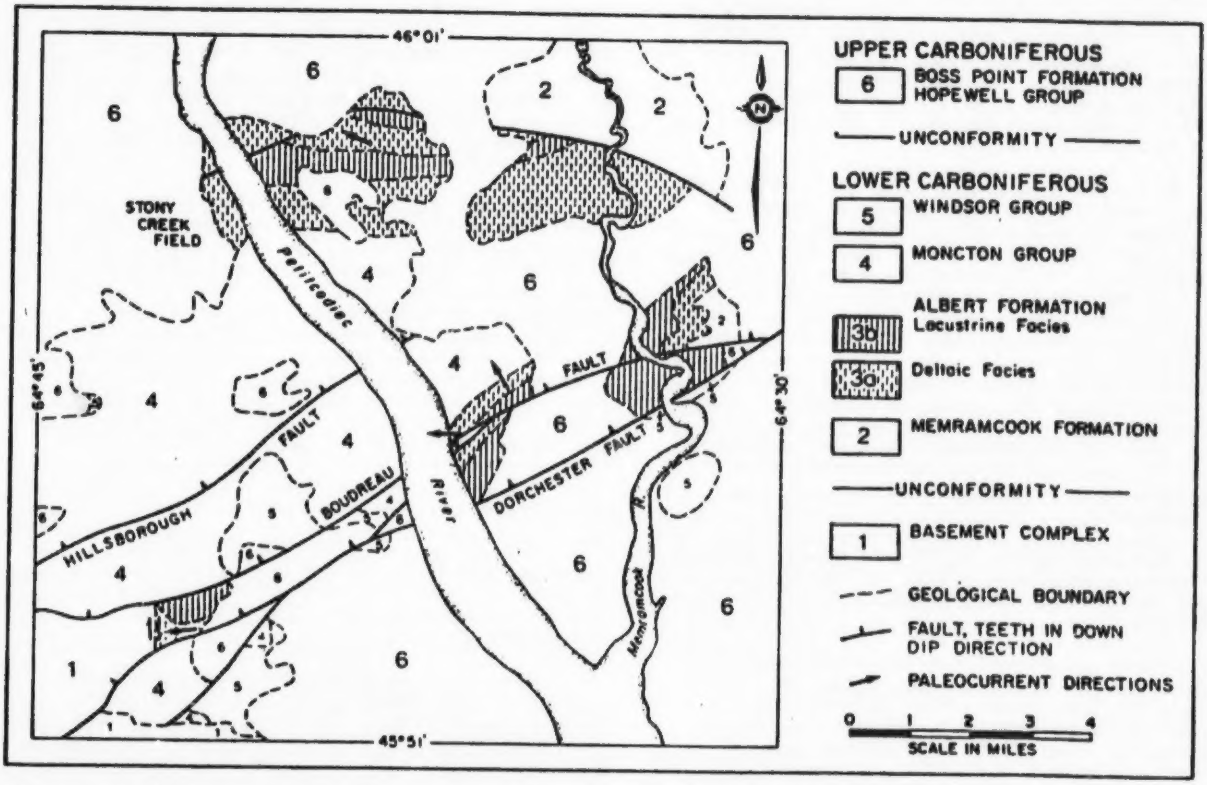

46°01'
45°51'
64°45'
64°30'
STONY CREEK FIELD
Petitcodiac
River
HILLSBOROUGH FAULT
BOUDREAU FAULT
DORCHESTER FAULT
FAULT
Memramcook R.
1
2
3a
3b
4
5
6
UPPER CARBONIFEROUS
6 BOSS POINT FORMATION HOPEWELL GROUP
UNCONFORMITY
LOWER CARBONIFEROUS
5 WINDSOR GROUP
4 MONCTON GROUP
ALBERT FORMATION
3b Lacustrine Facies
3a Deltaic Facies
2 MEMRAMCOOK FORMATION
UNCONFORMITY
1 BASEMENT COMPLEX
GEOLOGICAL BOUNDARY
FAULT, TEETH IN DOWN DIP DIRECTION
PALEOCURRENT DIRECTIONS
0 1 2 3 4
SCALE IN MILES

Figure 4. Geology of southeastern Moncton Subbasin (see figures 2 and 3 for location)

In the southwestern part of the Subbasin in the belt between Hampton and Sussex, the rocks are described as coarse-grained sandstone and conglomerate arranged into fining-upward fluvial cycles up to 35 m (110 feet) in thickness[9]. Current ripples and small-scale cross beds in the sandstone indicate a southwestern provenance[9]. South of Sussex, in the same belt, the rocks are mostly siltstone and mudstone with lesser interbedded current ripple-laminated sandstone. The siltstone and mudstone are commonly mudcracked and contain carbonate nodules. The sandstone beds show unidirectional transport towards the northeast[3]. The bed forms and abundance of vertically accreted siltstone and mudstone in this area suggest a topset delta environment[3].

Evaporites occur in the upper part of the Albert Formation at two locations: near Petitcodiac River in the southeast and 50 km (30 miles) west at Cornhill. In both localties the evaporites occur in the subsurface and were discovered by drilling negative gravity anomalies.

The evaporites are mainly impure rock salt, gypsum, anhydrite, limestone and lesser glauberite that occur as nodular and coalescing nodular beds intercalated with grey and red shale[11]. At Cornhill the rock salt and glauberite occur as a matrix and as stringers within mudstone[11]. The glauberite is generally interpreted to be a non-marine salt[12].

Both evaporite occurrences are associated with clastic deltaic strata. They apparently formed by rapid evaporation from small ponds of fresh water perched on a delta plain substratum.

Lacustrine strata in the Albert Formation have been the most frequently described rocks in the Moncton Subbasin. The oil shales have been investigated and discussed for well over 100 years. At one time all the Albert facies were believed to have been deposited in a lake[8,13]. The first regional lithofacies and paleoenvironmental study of the Albert was carried out in 1977 by Canadian Occidental Petroleum Limited[14]. The model set forth in this latter report was extended and applied to sections throughout the Subbasin[9].

The lacustrine facies (i.e. kerogen-bearing strata) crops out along the Caledonia Uplift from southeast of Sussex to southeast of the Stoney Creek Oilfield. Near the Uplift the kerogen-bearing beds are intimately associated with alluvial fan conglomerates and mudstones. South and east of the Stoney Creek Oilfield the lacustrine strata are interlayered with deltaic sandstone, siltstone and claystone. Lacustrine rocks are also exposed in the northeastern part of the Subbasin immediately south of the Indian Mountain Fault. There, the rocks are interbedded with fluvial sandstone.

The strata constituting the lacustrine facies have in the past been collectively described as oil shales. King in 1963 subdivided the oil shales into four lithotypes which he designated as marlstones and further described each type using suitable modifiers[15]. A variation of the marlstone classification has been used by subsequent workers[16]. The marlstone terminology has been found unsatisfactory for describing the rocks in outcrop. The mineralogical composition of the rocks fits none of the accepted AGI definitions of marlstone and it is recommended that the term be abandoned in describing the oil shales.

The lacustrine facies is characterized by four lithotypes: shale, siltstone, sandstone and blocky kerogen-rich dolomitic laminite.

Shale is one of the most abundant lithotypes in the lacustrine facies. It occurs in beds from a few centimetres up to sections several tens of metres in thickness. The rock ranges from grey to brown, the brown varieties typically containing higher organic matter. The shale is highly fissile, and the higher kerogen-bearing beds cleave into paper-thin flexible sheets. This property serves to distinguish the shale from all other rock types. The fissility results from alternating varves about 0.01 mm (0.004 inch) in thickness. The varves in the organic shales are defined by kerogen-rich and carbonate-rich layers[15]. X-ray diffraction and organic geochemical analyses[16] on 20 core samples indicate the shale contains by volume about 15 per cent dolomite, 9 per cent calcite, 57 per cent clastic minerals, and 19 per cent organic matter. The clastic fraction is largely composed of quartz with lesser amounts of feldspar, illite and mixed layer clays. Analcime is a locally abundant diagenetic mineral; it has been interpreted to form from clay mineral alteration in alkaline sodium-rich lake water[14,16]. Most samples of the shale contain 1 to 3 per cent pyrite. The pyrite is clearly diagenetic, it commonly forms as nodules, and is believed to result from a reducing environment associated with anoxic conditions in the lake sediments. Such reducing conditions have locally led to the preservation of articulated fresh-water palaeoniscid (bony) and osteolepid crossopterygian (lobe-finned) fish[8,13,17].

Siltstone is also an abundant rock-type of the lacustrine facies. It is best exposed along Memramcook River in the extreme southeastern part of the area (Figure 4) and at Indian Mountain in the northeast. The rock varies from massive to laminated and individual beds range from 2 cm (0.8 inch) up to 1 m (3 feet) in thickness. Successive interbeds form sections with an aggregate thickness in excess of 60 m (200 feet) in the Albert Mines area.

The siltstone is typically brown. The rock breaks with a hackly to subfissile fracture. The subfissile beds are characterized by continuous and slightly wavy laminations or discontinuous parallel "feathers" of kerogen[16]. The x-ray diffraction and geochemical data given by Macauley and Ball indicate the siltstone contains more dolomite, about 22 per cent, but less calcite, about 4 per cent, and organic matter, about 15 per cent, than the associated beds of shale. The clastic component constitutes 59 per cent of the rock and comprises quartz, feldspar, minor clay minerals, and locally analcime.

The siltstone contains dolomitic spherical bodies, 10 to 20 microns in diameter, that have been interpreted as the unicellular algae, Chlorellopsis coloniata Reis[15].

Sandstone is a minor lithotype of the lacustrine sequence. The rock occurs in beds ranging from 2 to 50 cm in thickness. The beds are typically massive but locally display subtle parallel laminations giving the rock a crude parting along bedding surfaces. Along Memramcook River, where the rock is best exposed, it is associated with and grades into beds of siltstone. The sandstone is grey to brown on fresh surfaces and light brown on weathered exposures. The rock is fine-grained, but may become coarser and contain a few matrix supported coarse grains and granules of quartz. King describes the sandstone (ie. his low-grade sandy marlstone) as consisting of detrital quartz and feldspar in a disorganized matrix of dolomitic ooze and organic matter. The organic content is approximately 14 per cent by volume. The inorganic minerals include dolomite (17 per cent), calcite (6 per cent) and clastic minerals (63 per cent). No analcime has been reported from the sandstone.

Kerogen-rich dolomitic laminite, like the sandstone, is a minor rock-type of the lacustrine facies. It has only been described from sections in the southeastern part of the Moncton Subbasin[14,15,16]. The rock is called blocky laminated marlstone by King and laminated marlstone by Macauley and Ball. As noted above, the rock is not a marlstone. It is similar to the organic-rich dolomitic laminite described from the Wilkins Peak Member of the Green River Formation[18].

The distinguishing characteristic of the laminite is its ubiquitous and rhythmic interlaminations of organic-rich and carbonate-rich varves. The varves are approximately 0.2 - 0.3 mm (0.004 - 0.006 inch) in thickness and commonly show evidence of soft sediment deformation and small-scale slump folds. This feature gives the laminae a wavy or crenulated appearance.

The laminite is not fissile like the associated beds of shale. The organic kerogen acts as a framework giving the rock a tough resilient character.

Optical examination of the laminite reveals the presence of organic fusiform bodies approximately ten to several hundred microns in length and other organic structures that may represent bacteria, fungi and algae[15].

The x-ray diffraction and organic geochemical data given by Macauley and Ball[16] shows that for 31 core samples the laminate averages by volume: 32 per cent organic matter, 13 per cent dolomite, 4 per cent calcite, and 51 per cent clastic minerals.

Tectonic History of the Albert Formation

The Moncton Subbasin formed by normal block-faulting in Late Devonian time. Succeeding its inception, and throughout Memramcook, Albert and Weldon time, the basin continued to subside. Following Weldon deposition, the Subbasin underwent a compressional event with renewed uplift of the basement rocks to the south and north. This resulted in a phase of open folding in the Albert Formation. A macroscopic west-plunging syncline of Albert strata is cored by younger rocks of the Moncton Group in the southeastern parts of the area (Figures 2 and 4).

Associated with these tectonic events, several major faults were initiated that greatly control the present distribution of the Albert Formation. Most of the faults are reverse and/or thrust structures that dip to the northwest[5].

Succeeding the compressional cycle and the resulting deposition of Hillsborough clastics, the Moncton Subbasin was transgressed by the marine Windsor Group. The Windsor is overlain by redbeds of the Hopewell Group. During Hopewell time a second major tectonic event occurred. In the southeastern part of the Subbasin upper Hopewell rocks unconformably overlie more steeply dipping pre-Hopewell rocks[2,4]. The Hopewell tectonic event rejuvinated the earlier formed faults leading to further displacement of the Albert Formation.

The Boudreau and Dorchester Faults in the southeastern part of the area (Figures 2 and 4) have greatly affected the distribution of the economically important oil shales. The amount of displacement on the two faults is unknown. Extensive tectonic melange zones along Petitcodiac River, numerous tectonic breccia zones along Memramcook River, and recumbent folds in the Albert Mines area imply the displacement was large.

Conclusions

A preliminary study of the facies distribution and sediment transport directions in the fluvial and deltaic strata of the Albert Formation shows that detritus was transported from the southwest in the western part of the Moncton Subbasin. In the eastern part of the area paleocurrents were from the southeast and east towards the west. The deltaic facies apparently defines the margin of a lacustrine sequence which lies buried in the axial region of the Subbasin.

Debris flow conglomerates interbedded with kerogenous fine-grained strata along the Caledonia Uplift in the south, imply that the kerogen-bearing rocks in this area are marginal lake deposits and that deeper water and possibly higher grade oil shales lie down the paleoslope to the north.

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POOR

QUALITY

ORIGINAL